Table 7

Recent reported and estimated groundfish catches in the Western Central Atlantic, by area and type of fishery, including shrimp trawl discards, in '000 tons

Location	Industrial	Food	Recrea-tional	Discards	Total
Southeastern U.S.	-	1	20 1/	32 2/	53
U.S. Gulf of Mexico	45 3/	5 3/	58 1/	600-1000 4/	710-1110
Mexico	20 5/	30 6/	-	120-150 7/	170-200
Belize-Venezuela	-	50 8/	-	50-100 9/	100-150
Guianas-Brazil	-	50 10/	-	200 11/	250
TOTAL :	65	135	80	1000-1500	1280-1760

1/ Estimated from unpublished data for 1975, made available by Deuel, excluding pelagic and reef species and sharks

2/ Average for 1973-75 from Keiser (1977), based on heads-on discard ratios ranging from 1.2 to 4.0

3/ 1969-76 averages

4/ From Klima (1976), calculated from reported 90% C.L. discard ratios and 1972-74 U.S. shrimp catch for individual statistical areas

5/ Average of reported Cuban 1966-74, and Soviet trawl catches, excluding large catch (70,000 tons) in 1972

6/ Reported landings of miscellaneous demersal species in 1972 (Klima, 1976a)

7/ Calculated from reported 1972-74 Mexican shrimp catch and assumed heads-on discard ratio of 8.3 ± 0.75 reported by Klima (1976)

8/ Based on reported 30,000 tons from Venezuela in 1977 plus reported and unreported landings in other countries

9/ Based on estimated average shrimp catch during late 1970's times discard ratios of 5.0 and 10.0

10/ Includes 1977-78 landings of catfish in northern Brazil (25,000 tons) and 15,000 tons of by-catch landed by shrimp trawlers in Guyana

11/ Western Central Atlantic Fishery Commission, 1979

Table 8

Estimated annual 1972-74 groundfish discards for U.S. Gulf of Mexico shrimp fleet calculated from whole weight discard ratios and reported shrimp landings by statistical area in '000 tons

Statistical area	Discard ratio	Confidence limits	Shrimp Catch 1972	1973	1974	Groundfish Discards 1972	1973	1974
11	17.1	± 3.8	6.0	2.8	3.5	102	47	60
12	7.1	± 2.4	0.3	0.2	0.1	2	2	1
13	20.2	± 1.9	5.3	4.5	4.1	107	90	82
14	20.0	± 3.0	3.0	1.6	1.4	61	33	28
15	15.8	± 3.3	7.8	5.1	5.8	122	80	91
16	10.8	± 3.1	4.5	3.4	2.8	49	37	30
11-16 inshore	3.1	± 0.9	18.5	12.9	13.9	58	40	43
1-10	8.3	± 0.8	8.9	11.0	11.6	73	91	96
17-21	7.0	± 3.0	36.1	27.1	30.0	252	190	210
22-30	8.3	± 0.8	6.2	4.1	4.8	52	34	39
31-40	8.3	± 0.8	2.5	3.2	1.7	21	27	22
17-21 inshore	3.1	± 0.9	5.2	6.3	4.2	16	20	13
Total Gulf average			104.2	82.3	83.8	914	690	715
90% C.L.						±117	±86	±95

Source: Klima (1976)

Table 9

Annual 1972-78 catch, fishing effort and catch-per-unit-effort data for industrial catfish fishery in Belém, Brazil

Year	Catch (tons)	Effort (days at sea)	Catch-per-unit-effort (tons/day at sea)
1972	845	144	5.88
1973	6,447	1,059	6.09
1974	11,853	2,795	4.24
1975	15,070	3,371	4.47
1976	15,767	3,075	5.13
1977	22,486	3,360	6.69
1978	17,446	3,164	5.51

Source: Programa de pesquisa e desenvolvimento pesqueiro do Brasil, 1979

Table 10

Density and biomass estimates for all species caught in trawls and for demersal teleosts only, by depth zone, in the southeastern United States as determined from 1973-75 MARMAP trawl surveys

Depth (m)	Density (tons/km^2) 1/		Area (10^3 km^2)	Biomass ('000 tons)	
	All species	Demersal teleosts		All species	Demersal teleosts
10-18	7.3	2.7	18.4	134	50
19-27	7.3	2.7	16.1	117	43
28-55	5.7	2.1	22.1	127	47
56-110	5.7	2.1	4.8	27	10
111-183	2.4	0.9	3.6	9	3
184-366	0.6	0.2	9.4	6	2
Total : (all depths)	5.4	2.0	74.5	420	155

1/ Original density estimates given by Barans & Burrell (1976) were divided by a catchability coefficient of 0.30

Table 11

Density and biomass estimates for all species caught in trawls and for demersal teleosts only as determined from MARMAP surveys during four different seasons in 1973-75 in the southeastern United States

Season/Year	Density (tons/km^2) 1/		Biomass ('000 tons) 2/	
	All species	Demersal teleosts	All species	Demersal teleosts
Fall, 1973	4.3	1.6	325	120
Spring, 1974	7.7	2.9	580	215
Summer, 1974	3.2	1.2	242	90
Winter, 1975	5.4	2.0	408	151
Mean (all seasons)	5.4	2.0	402	150

1/ Original density estimates given by Barans & Burrell (1976) were divided by a catchability coefficient of 0.30

2/ Total (non-reef) area equal to 75,000 km^2

Table 12

Mean biomass estimates for groundfish in inshore waters in the U.S. Gulf of Mexico as determined from trawl surveys, with associated minima and maxima at 95% confidence levels, in '000 tons

Area	Depth (m)	Mean biomass	Minimum	Maximum
Florida west coast 1/	0-110	753	611	895
Mississippi (88°-89°30'W) 2/	4-91	483	222	744
Louisiana (89°30'-91°30'W) 2/	4-91	754	375	1133
Louisiana (91°30'-94°W) 3/	0-110	467	-	-
Texas 4/	0-110	224	193	255
TOTAL :		2681	1868 5/	3494 5/

Source: Klima, 1976

1/ NMFS Pascagoula Laboratory exploratory surveys
2/ Average of four MARMAP surveys, 1973-74
3/ Presumably determined from NMFS Pascagoula and Galveston Laboratory surveys
4/ Average of surveys carried out by Pascagoula and Galveston Laboratories
5/ Includes 467,000 tons from western Louisiana

Table 13

Estimated 1976 groundfish catch for the northern Gulf of Mexico (87°30'-91°30'W) by fishery, in '000 tons

Fishery	Catch
Shrimp (discards)	292 1/
Industrial trawl	45
Commercial foodfish trawl	3.7
Recreational	20 2/
TOTAL :	360

1/ Based on a fish/shrimp discard ratio (whole weight) of 14:1 as determined from 1975 and 1976 surveys and 1976 shrimp catch

2/ Estimated as one-third the reported recreational groundfish catch for the entire Gulf in 1975 (Deuel, unpubl.data)

All commercial catch data taken from Gulf of Mexico FMC Groundfish Management Plan, 1978

Table 18

Density of groundfish stocks in Guyana, Surinam and French Guiana as estimated from trawl surveys

Survey	Location	Depth (m)	Density ($tons/km^2$)
La Salle	Surinam	9-37	16.5
Coquette	Surinam	9-37 37-183	15.9 4.0
Calamar	Surinam, French Guiana	9-37	6.8
Oregon II	Guyana, Surinam, French Guiana	37-183	7.0

Source: Klima (1976)

Table 19

Biomass estimates for groundfish stocks in northern Brazil inferred from densities reported from trawl surveys in the Guianas

Location	Depth (m)	Area 1/ (10^3 km^2)	Biomass 2/ ('000 tons)
Cabo Orange - Rio Pará (5^o-0^oN)	0-49 50-200 0-200	106 65 171	740-1700 260-455 1000-2155
Rio Pará - Parnaîba (0^o-3^oS)	0-49 50-200 0-200	83 40 123	580-1330 160-280 740-1610

1/ Area estimates from Yesaki (1974)

2/ Biomass estimated from minimum and maximum densities given in Table 18 for 9-37 m (equals 0-49 m) and 37-183 m (equals 50-200 m)

Table 20

Standing stock and potential yield estimates ('000 tons) for groundfish on continental margins of the Western Central Atlantic

Location	Standing stock	Methods	Potential yield	Methods	Source
Southeastern U.S.	400 1/	Trawl surveys 2/	50	Yield equation with M=0.50, F=0.20	Barans & Burrell, 1976
U.S. Gulf of Mexico	1870-3500	Trawl surveys	800-1500	Yield equation with M=0.50, F=0.35	Klima, 1976
Northern Gulf of Mexico ($87^{0}30'$-$91^{0}30'$W)	1240	Trawl surveys	490	Yield equation with M=0.50, F=0.30	Gulf of Mexico FMC, 1978
	-	-	330	Surplus production model 3/	Gulf of Mexico FMC, 1978
Campeche Bank	800	Trawl surveys	80-160	Yield equation with Z=0.20, Z=0.40	Klima, 1976a
Central America	-	-	150 4/	Average catch/km^2	Munro & Thompson, 1973
Colombia - Venezuela	-	-	130 4/	Average catch/km^2	Munro & Thompson, 1973
Colombia - Guiañas	1200	Trawl surveys	315	Yield equation with M=0.50, F=0.0	Klima, 1976
Northern Brazil (5^{0}N-3^{0}S)	1700-3800	Trawl surveys	425-950	Yield equation with Z=0.50	Klima, 1976

Does not include "live-bottom" areas

Original density estimates adjusted for q=0.30

Commercial catch and effort data only

All demersal species

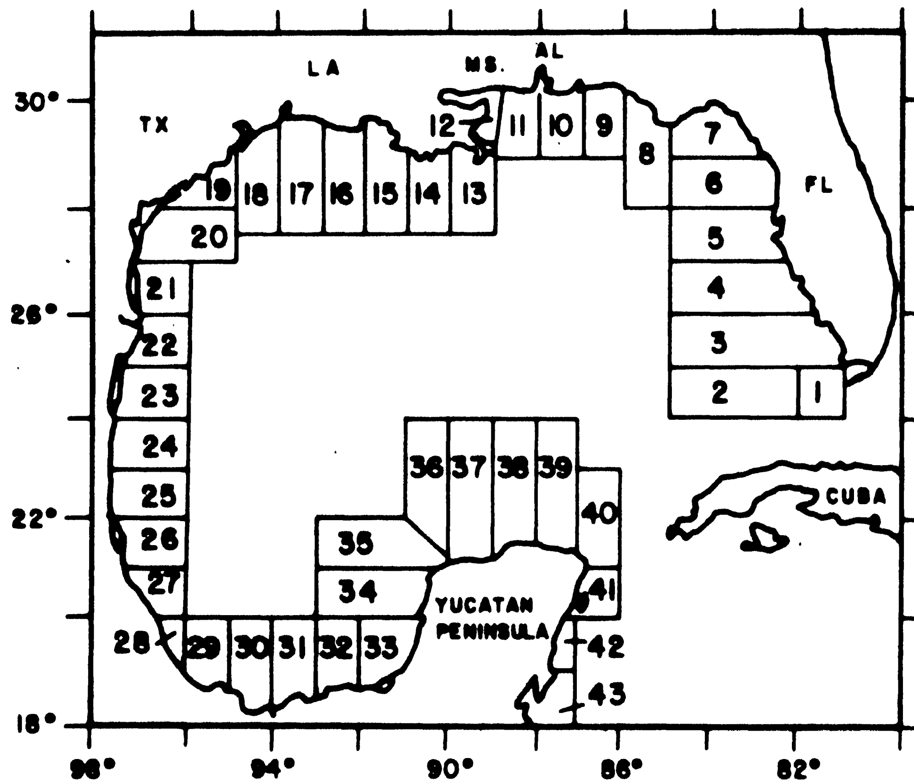


Figure 2 U.S. National Marine Fisheries Service statistical areas in the Gulf of Mexico

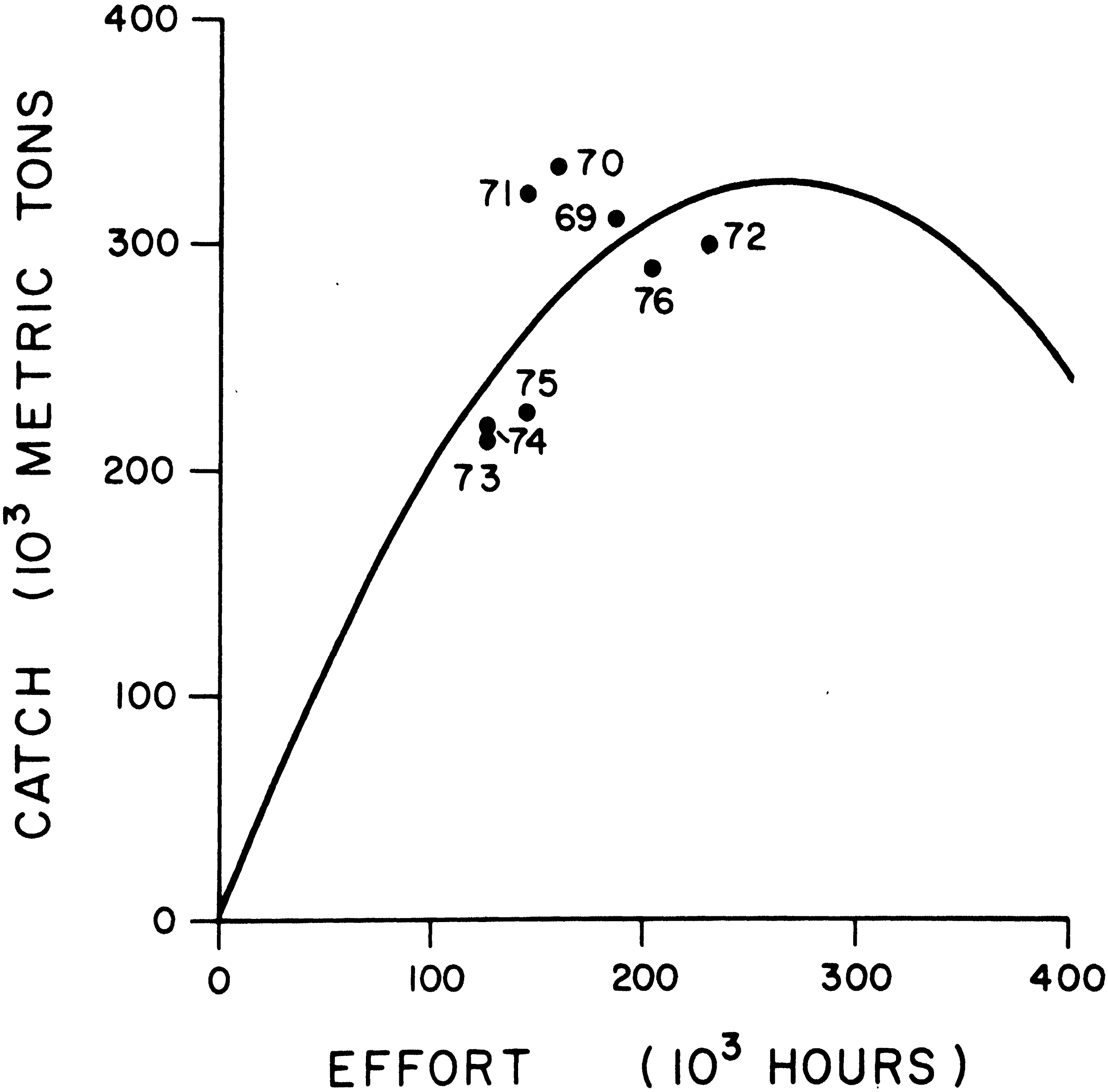


Figure 3 Annual estimated 1969-1976 groundfish catch and effort by the shrimp and foodfish trawl fisheries in the northern Gulf of Mexico ($87^o30'$-$91^o30'$W) and the predicted yield curve (Source: Gulf of Mexico FMC, 1978)

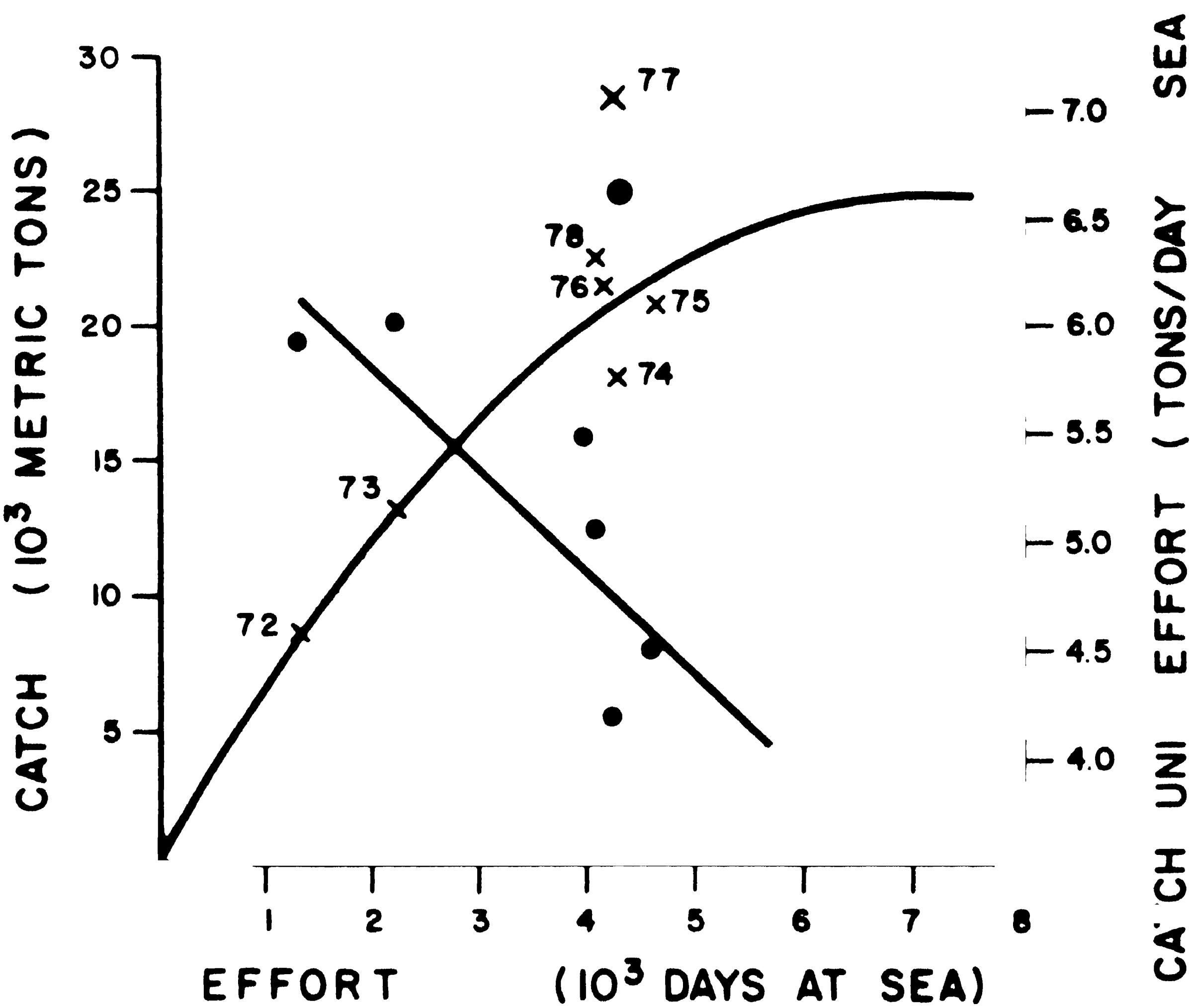


Figure 4 Linear regression of 1972-1978 CPUE versus effort for the catfish (*Blachyplastystoma vaillant*) trawl fishery of northern Brazil and the predicted yield curve. The 1977 data (shown as a pronounced O and X) were omitted from the analysis (Source: Programa PDP do Brasil, 1979)

CHAPTER 3: SHARKS

Reported commercial landings of sharks, rays and skates in statistical area 31 of the Western Central Atlantic averaged 11,500 tons between 1973 and 1978 (Table 4). Most of the reported landings were from Cuba and Mexico. Paiva *et al.* (1971) estimated that an additional 1,200 tons were produced annually by artisanal fishermen in northeast Brazil between 1960 and 1968. Reported landings certainly underestimate actual catches when sources such as recreational fisheries, trawl discards and incidental catches are considered. The total 1978 estimated catch of inshore (200 m) shelf species from the U.S. Gulf of Mexico was 7,600 tons (Table 21).

The only directed commercial fisheries for sharks in the Western Central Atlantic are currently conducted by Mexico on Campeche Bank and Cuban vessels which operate on the north coast of Cuba. The Mexicans reported average catches of 2,000 tons between 1975-1978 (FAO, 1979). These were primarily large carcharhinid sharks captured with longlines and setlines. Reported Cuban landings for the same period averaged 3,300 tons. Small quantities are captured incidentally to Cuban snapper/grouper longline fishing on the west coast of Florida and Campeche Bank and by Japanese tuna longliners which operate in the Gulf of Mexico.

Most of the directed commercial and recreational shark fishing activity is for the larger inshore species. According to the Gulf of Mexico FMC (1979), U.S. recreational fishing produced mostly bull (*Carcharhinus leucas*) and tiger (*Galeocerdo cuvieri*) sharks in the Gulf of Mexico. For the smaller sharks, the principal species discarded by the U.S. shrimp fleet or caught by recreational fishermen in the 1970s were Atlantic sharpnose (*Rhizoprionodon* spp.), bonnethead (*Sphyrna tiburo*) and blacktip (*Carcharhinus limbatus*) sharks.

Sharks, in general, are particularly vulnerable to exploitation given their low fecundity, advanced age-at-maturity and slow growth. This is less true for other elasmobranchs which have higher reproductive potentials. Many shark species are migratory. Some of the larger species migrate over long distances.

Shark resources in the region are underutilized. Bullis *et al.* (1971), on the basis of U.S. exploratory fishing surveys in the 1950s and 1960s, estimated a total biomass of 370,000 tons for inshore shelf waters and 228,000 tons for offshore waters in statistical area 31. These estimates were based on an average offshore density of 36 kg/km^2 and an inshore density of 270 kg/km^2. The inshore estimate was based on catch records obtained from handline and bottom longline gear sets and from incidental trawl catches. Supporting information was available from FAO exploratory fishing surveys and a survey of 160 major river systems.

Trawl surveys conducted on the southeast coast of the U.S. in 1973-1975 resulted in a standing stock estimate for sharks, skates and rays of approximately 220,000 tons after the original catch rates (Barans and Burrell, 1976) were adjusted for a catchability coefficient of 0.30 according to standardization procedures outlined by Klima (1976a).

The general yield equation (Y_{max} = 0.5 MB) derived by Gulland 1971) to estimate potential yield from virgin biomass does not apply to shark populations since they are characterized by low reproductive potential and a strong density-dependent stock/recruitment relationship. The ratio of maximum yield to virgin biomass for shark populations in the Gulf of Mexico was therefore determined for five groups of species in the Gulf of Mexico (Gulf of Mexico FMC, 1979) from life history data, following conceptual methods outlined by Holden (1974). Fifty-nine species of sharks and forty species of skates and rays were divided into five groups according to habitat (depth) and size (age-at-maturity greater or smaller than 5 years). Based on the results of experimental shark fishing off the north coast of South America and personal commentary by S. Springer, the biomass of small sharks in the Gulf was assumed to equal 1-2 times the biomass of large stocks in both inshore and offshore waters when the biomass of large sharks was set equal to 50% of the total biomass. The biomass of skates and rays was assumed to be 3-6 times lower than the total estimated minimum shark biomass in inshore waters (Table 22). All biomass estimates were assumed to be for unexploited populations and were based on average density estimates in Bullis *et al.* (1971).

The growth parameter (K) was estimated for major species from data on the gestation period of female sharks, length at birth, and L_∞, and averaged 0.20 (range 0.13-0.42). Total mortality (Z) rates were based on an upper limit value of Z which just allows the population to replace itself every year and on age-at-maturity and the average number of offspring per year per female. Natural mortality (M) was estimated as 50-90% of Z, based on computed values of Z and M for several species (Holden, 1974). Total mortality (Z) values ranged from 0.29-0.75 (mostly 0.35-0.55) and M from 0.15-0.67 (mostly 0.20-0.48).

Rather than predict the maximum yield/recruit, since recruitment is a critical factor for sharks, recruitment (R) was expressed relative to recruitment of the virgin population (R_0) and related to current biomass (B), the biomass of the virgin population (B_0) and the biomass of the populaton at maximum sustainable yield (B_{MSY}). R_{MSY} was assumed to correspond to R_0, though this might be optimistic and lead to overestimation of potential yield. The version of the Ricker stock/recruitment model which was used implies nearly constant recruitment at low stock size, but allows for a decline in recruitment when the population is substantially reduced.

The stock/recruitment relation was converted to eliminate biomass terms and inserted into the Beverton-Holt yield equation which was then solved for MSY. The ratio MSY/B_0 was predicted for given parameter estimates. In these calculations, the age-at-recruitment (t_R) was assumed to equal age-at-first-capture (t_c) and effort was assumed to be non-selective with respect to age and sex. Computed values of the ratio MSY/B_0 ranged from .035-0.131 (mostly 0.05-0.10) with fishing mortality (F)=0.10-0.34. The critical parameter was M, not K. When size at recruitment l_R was set equal to 0.5 L_∞, the ratio MSY/B equalled 0.25 M in all cases. Accepting an approximate mean value of M equal to 0.3 for all species, the ratio of maximum sustainable yield to virgin biomass was 0.075 and the biomass at MSY was 0.385 times B_0.

The results suggested that maximum yields are obtained from shark populations in the Gulf of Mexico at half the population size predicted by the Gulland yield formula. Furthermore, with M=0.3, MSY would be achieved when yield equals 7.5% of the virgin biomass and the exploited biomass equals 38.5% of the virgin biomass. If anything, these results lead to overestimates of MSY since Holden (1974) estimated MSY/B_0 ratios of 0.03 to 0.05 for cool and temperate water shark species. Possible errors in parameter estimation would cause the MSY/B_0 ratio to be overestimated. Holden limited K values to the range 0.1-0.2 and used higher estimates of age-at-maturity.

Maximum sustainable yield was therefore estimated for each shark species group by multiplying virgin biomass estimates times 0.075. For skates and rays, a factor of 0.10 was used. The value for sharks was based on a range of MSY/B_0 ratios equal to 0.04-0.15 for five species and may be low since no skates, which are more fecund, were included. Total MSY for the Gulf of Mexico may therefore be in the range 16,000 to 25,000 tons/year (Table 23).

As far as can be determined, the present catch of some of the larger sharks in inshore waters of the Gulf may be nearing MSY. Species which are probably being harvested at or near MSY are bull shark (_Carcharhinus leucas_), lemon shark (_Negaprion brevirostris_) and dusky shark (_Carcharhinus obscurus_). The smaller species are not yet in any danger of over-exploitation. The 1978 estimated catch of skates and rays (2,500 tons) is near to their MSY, but the stocks are not believed to be over-exploited since: (1) the current biomass probably still exceeds B_{MSY}, (2) some proportion of the skates and rays discarded by trawlers survives, and (3) the MSY estimate is a conservative one. In general, relative changes in biomass and/or fishing mortality were recommended (Gulf of Mexico FMC, 1979) as more useful stock evaluation criteria than changes in yield relative to MSY since the model predicts yield on an equilibrium basis. This is because shark populations take so long to "adjust" to gradual changes in fishing effort such as those which have taken place in the Gulf of Mexico during the last 10-20 years largely as a result of increased recreational fishing.

Applying the formula $MSY=0.075\ B_0$ to the standing stock estimates of Bullis _et al_. (1971) and inshore (< 200 m) and offshore area estimates for the entire WECAFC region (2.0 million and 13.4 million km^2, respectively) produced maximum potential yield estimates of 28,000 tons for inshore shelf areas and 17,000 tons offshore. Assuming present catch is in the order of 20,000 tons, twice the reported catch in area 31, this resource is underutilized. Full utilization of shark resources requires the production of marketable shark products.

There seem to be very few obstacles preventing the harvest of sharks. Exploratory fishing surveys conducted between 1968 and 1970 by FAO off the northeast coast of South America with setlines, handlines and longlines produced substantial catches of shark, mostly Carcharhinus limbatus and Carcharhinus porosus (Kleijn, 1974). Catches in excess of 200 kg/hr were obtained with handlines in the more productive areas. Brazilian surveys in 1971-1973 confirmed the presence of large sharks in coastal waters between 6°40'S and 8°50'S (Vieria Ferreira, undated MS).

Table 21

Estimated 1978 catch of inshore shelf elasmobranchs in U.S. Gulf of Mexico ('000 tons)

Source	Large sharks	Small sharks	Skates & rays	Total
Recreational fishing	1.7 1/	0.7 2/	0.5	2.9
Trawl fishery discards 3/	0.8	1.6	2.0	4.4
Other 4/	0.2	0.1	-	0.3
TOTAL :	2.7	2.4	2.5	7.6

Source: Gulf of Mexico Fishery Management Council, 1979

1/ Estimate based on 1977-78 NMFS Billfish/Shark survey (sharks larger than 10 kg)

2/ Estimate based on interviews

3/ Estimate based on 1974-77 NMFS Shrimp Discard Study

4/ Includes commercial fishery, by-catch from snapper-grouper fishery, and miscellaneous sources of mortality

Table 22

Estimated biomass of large and small sharks and skates and rays in inshore and offshore waters of the U.S. Gulf of Mexico

	BIOMASS (in '000 tons)		
	Inshore	Offshore	Total
Large (t_m > 5 yrs) sharks	75	20	95
Small (t_m <5 yrs) sharks	75-150	20-40	95-190
Skates and rays	25-50	-	25-50
TOTAL :	175-275	40-60	215-335

Source: Gulf of Mexico FMC, 1979

Table 23

Estimated maximum sustainable yields for sharks, skates and rays
in the U.S. Gulf of Mexico

	MSY ('000 tons)		
	Inshore	Offshore	Total
Large sharks	5.6	1.5	7.1
Small sharks	5.6-11.2	1.5-3.0	7.1-14.2
Skates, rays	2.0-20.6	-	2.0- 3.8
TOTAL :	13.2-20.6	3.0-4.5	16.2-25.1

Source: Gulf of Mexico FMC, 1979

CHAPTER 4: REEF FISH

Demersal fish populations which inhabit reef areas in the Western Central Atlantic are composed of a large number of species which can be grouped into two management units, shallow-water reef species and deep-water reef species. The shallow-water fauna is more diverse, and is composed of smaller species such as grunts, squirrel-fish, parrotfish, groupers and snappers. These stocks are harvested primarily with fish traps on island shelves and oceanic banks throughout the Caribbean. In deeper water near the shelf edge, the smaller species of snapper and grouper are replaced by species such as silk snapper, blackfin snapper, vermillion snapper and groupers belonging to the genera Mycteroperca and Epinephelus. The deep-water fauna is also harvested in traps, but the most common gear is the handline. Major fisheries exist in the northern Gulf of Mexico and on Campeche Bank with some additional fishing off the coasts of the southeastern U.S., Central and South America and in the Caribbean islands. Exploratory fishing surveys have demonstrated the présence of significant under-utilized deep-water snapper and grouper resources on island shelves and offshore banks in the Caribbean (Wolf and Chislett, 1974; Sylvester, 1974; Thompson, 1978; Boardman and Weiler, 1980).

Reef fish populations share several biological characteristics which make them vulnerable to low-intensity fisheries and which justify the inclusion of such a wide variety of species in a single management unit. In general, they are long-lived species with low growth rates. They are also very sedentary, maintaining residence on a single reef and only making daily short-range migrations to and from adjacent feeding areas. Also, population size is often limited by the amount of available reef habitat and recruits may be derived from the transport of planktonic larvae from "upstream" reefs (Huntsman and Manooch, 1978). Coral reefs exist as productive "oases" in otherwise infertile tropical waters, but since most of the energy produced by the ecosystem is recycled within it, there is theoretically little left over to support sustained yields (Stevenson and Marshall, 1974). It comes as no surprise, therefore, that intense exploitation of the shallow-water reef fauna with traps has resulted in low catches, changes in species composition, and reduced mean sizes at capture in such locations as the Jamaican south coast (Munro et al., 1971). Similar trends have been observed for deep-water snappers in the Gulf of Mexico (Allen and Tashiro, 1976).

It is difficult to document catches of demersal reef fish in the WECAFC area due to the great variety of species which are landed. Only a few individual species are identified. Reported commercial landings of grunts, snappers, and groupers averaged 72,000 tons during 1970-78 in statistical area 31 (Table 4). The actual commercial catch of reef fish is probably much higher since other species are not included and since a large but unknown proportion of the artisanal catch is not reported. Munro (1977) estimated a 1968 catch of about 100,000 tons of neritic species from island shelves and offshore banks in the Caribbean and Bahamas. U.S. recreational catches of 30,000 tons (grunts, groupers, sea bass, porgies and snappers) were reported from the Gulf of Mexico and the South Atlantic Bight in 1975 (Deuel, unpublished data). Although this last estimate may be exaggerated, there is little doubt that the U.S. recreational catch of snapper and grouper exceeds the U.S. commercial catch (6,800 tons in 1977). Total reported Brazilian landings of reef species averaged 11,600 tons between 1970 and 1978 (Table 24). Most of this catch was presumably from the WECAFC region.

United States

According to Allen and Tashiro (1976), the U.S. commercial snapper-grouper fishery started in Florida in 1830-1840. By the early part of this century, the fishery had expanded to include most of the grounds in the Gulf of Mexico, including Campeche Bank. The use of the fathometer and the conversion to mechanical reels permitted fishing in deeper water by the late 1940s and 1950s. The U.S. fishery moved from Campeche to Honduras and Nicaragua in 1964, and to Colombia in 1970. By 1974, grounds in the South Atlantic Bight and the Bahamas were being exploited. Most of the U.S. catch is taken with handlines in depths up to 140 fms, although 15-60 fms is the most productive zone. At least 17 species of snapper and 15 species of grouper are harvested from the Gulf and other species are caught as incidental catch.

Total U.S. commercial landings (all reef species) were stable at about 9,000 tons during 1957-1976 except for a short period of higher production in 1964-65, when the U.S. fleet was actively fishing red snapper on the Campeche Banks. Over half the U.S. catch of red snapper was taken from foreign shores

in 1966, but less than 13% was derived from waters outside the U.S. after 1973 (Gulf of Mexico FMC, 1979a). Red snapper (referring to several species, but mostly Lutjanus campechanus) accounted for 41% of the U.S. commercial landings during 1972-76, grouper and scamp 34%, and jacks 10%. Most of the snappers in the Gulf of Mexico are currently harvested in the north central Gulf while most groupers are caught on the west coast of Florida. Reported U.S. commercial landings of snapper and grouper in statistical area 31 ranged from 6,900 to 9,500 tons a year between 1970 and 1978 (Table 25).

A fleet of Cuban vessels on the Florida shelf harvested between 1,600 and 2,300 tons a year between 1971 and 1975. Cuban fishing vessels have operated off Florida and Mexico at least since the 1850s (Tashiro and Coleman, 1977). Total Cuban catch reached a high of 5,000 to 7,000 tons in the 1940s and 1950s (Gulf of Mexico FMC, 1979a). The principal gear since 1965 has been the longline and the principal species captured is the red grouper (Epinephelus morio). Cuban vessels have been restricted from U.S. waters in recent years.

A relatively small U.S. commercial reef fishery is based in the South Atlantic Bight. Landings fluctuated irregularly between 1967 and 1973 and averaged 2,200 tons a year. Total commercial landings in 1977 were 2,550 tons: species of grouper and snapper accounted for 2,000 tons., Total recreational landings from this area were estimated at 4,400 tons in 1977 (South Atlantic FMC, 1978). Two important species in the offshore headboat fishery which do not extend south of Florida are porgy (Pagrus pagrus) and black sea bass (Centropristis striata). The reef fauna in the South Atlantic is sharply divided into a tropical fauna along the shelf edge (70-200 m) and a migratory nearshore (30-70 m) fauna which is associated with zones of invertebrate and algal growth near rock outcroppings, the so-called "live-bottom" habitat. Seasonably cold temperatures preclude the survival of the shallow-water reef fauna typical of tropical waters (Huntsman and Manooch, 1978).

Mexico

Average annual east coast Mexican catches of snapper and grouper in 1970-78 were 3,300 and 11,800 tons respectively (Table 26). All reported grouper landings and 60% of the snapper landings in 1963-72 were landed in the states of Yucatan, Campeche and Quitana Roo (Klima, 1976a) and were assumed to come from Campeche Bank. Applying these estimates to the 1970-79 commercial catch from Campeche Bank produced a total average annual catch in 1970-78 of 14,000 tons of snapper and grouper for the Mexican fleet operating on the Bank. Total Mexican landings of snapper and grouper have been fairly stable over the past six years: Lutjanus campechanus accounts for two-thirds of the Mexican snapper catch. Current reported grouper (E. morio) landings in Cuba are less than 4,000 tons and presumably were largely caught on Campeche Bank. The average Cuban catch of grouper from Campeche between 1967 and 1974 was 4,700 tons (Klima, 1976a). Currently, therefore, the total annual catch of snapper and grouper from the Bank is estimated to be 8,000 tons. This estimate does not include other demersal species caught with handlines or longlines or any finfish caught incidentally by shrimp trawlers.

Soviet and Cuban trawlers were active on the Banks in the late 1940s and early 1970s and produced over 50,000 tons of grunts in 1972 and 1975, but since 1976 trawl fishing has been suspended. Klima (1976a) reported that an estimated one-third of the 1973-74 Cuban trawl catches was composed of snapper and grouper (24% snapper). The total catch of snappers and groupers on Campeche Bank may have reached 30,000-40,000 tons in 1972 and 1975 and presumably included a large proportion of small fish. The impact of large-scale trawling operations on reef fish populations must be considerable, even though the rugged bottom areas on the shelf slope are not trawlable. The discards and unreported by-catch of commercial shrimp trawlers are additional sources of fishing mortality which must be considered. No assessment of this fishery which properly considers all of these components of the total catch of reef species has been published.

Central America

Catches of snapper and grouper by U.S. vessels which fished off the coast of Honduras and Nicaragua during 1965-71 reached 1,300 tons (Allen and Tashiro, 1976). No catches are reported by the Central American countries from this area, although Arostegui (MS) reported exploratory catches of

snapper and grouper (60-140 m) off Nicaragua. Venezuela has reported annual catches of 1,000-1,5000 tons of grouper and almost 4,000 tons of snapper in recent years. Recently, Venezuelan snapper vessels have been operating off French Guiana.

Brazil

Total reported Brazilian landings of snapper and grouper averaged 11,600 tons between 1970 and 1978 (Table 24). Twenty percent of this production was the snapper (*Lutjanus purpureus*), 32% was yellowtail snapper (*Ocyurus ocyurus*), and 32% was the grouper (*Epinephelus morio*). It is assumed that most of this catch came from areas of hard bottom (rock, coral) north of 10°S latitude. Snapper have been harvested on the north coast of Brazil since 1961 with longlines. Initial high catches attracted a larger number of vessels and landings increased rapidly to 4,860 tons in 1967, then declined to 1,900 tons in 1970 (Programa de PDP do Brasil, 1978). Since 1970, reported landings have again increased to 6,570 tons in 1977 (Table 27). Landings of *E. morio* declined from 3,000 tons in 1970 to less than 2,000 tons in 1976, but reached 4,000 tons in 1977 and 1978 (Table 24). A similar recovery was noted for yellowtail snapper. Red snapper landings reported by SUDEPE (Table 27) were higher than landings reported by FAO (Table 24).

Assessments

Caribbean islands and continental shelves

Assessments of the demersal reef fish resources in the Caribbean have been hindered by the lack of reliable effort statistics for the different gears used to harvest these stocks and the multiplicity of exploited species. The problem of collecting reliable effort data is compounded by the need to standardize effort relative to the fishing power of different gears such as traps, handlines and longlines which harvest the same stocks. Management is also complicated by the fact that small populations inhabiting individual reefs may constitute different unit stocks.

Munro and Thompson (1973) predicted a maximum yield of 4.1 tons/km^2 for all neritic reef species in Jamaica based on the relationship of catch/unit effort and effort/unit area for individual Jamaican parishes. Comparing the primary productivity of the region to that which has been observed in other areas, Gulland (1971) predicted yields between 1-10 tons/km^2 of shelf area in the Western Central Atlantic and speculated that one-eighth to one-quarter would be composed of demersal species and 0.1-0.2 tons/km^2 would be snappers and groupers. Applying these proportions to Munro's estimated maximum yield of 4 tons/km^2, Klima (1976) speculated that 0.5-1.0 tons/km^2 of demersal species and 0.1-0.2 tons/km^2 of snapper and grouper could be harvested by active demersal fisheries on reefs and shelf areas in the region. Munro (1977) considered 1.1 tons/km^2 as an average catch rate typical of active demersal reef fisheries in the Caribbean. Applying catch rates of 1.0 tons/km^2 and 0.2 tons/km^2 to area estimates (depths < 200 m), and assuming a 50% reduction in yield for the Bahamas where primary productivity is lower, produced estimates of potential yield for mainland shelf areas of Central and South America (not including the Guianas and Brazil) and insular shelf areas and banks of 275,000 tons3/ and 280,000 tons, respectively, for all demersal species and 55,000 tons for snapper/grouper in each area.

Potential yield estimates based on such broad generalizations are not very reliable. A maximum catch rate of 4 tons/km^2 for all neritic species may not be sustainable in a closed ecosystem like a coral reef where most of the production is recycled and is not available to support extensive exploitation. An average yield of 1 ton/km^2 for demersal species seems more reasonable. Assuming 280,000 tons does represent a conservative estimate of potential yield for demersal reef fisheries in the Caribbean, present production (estimated at 100,000 tons in 1968 by Munro, 1977) could at least be doubled. Although reliable catch statistics were not available, a large percentage of the catch of reef species in the Caribbean is probably snapper and grouper. Exploratory fishing has shown that snapper/grouper stocks in deeper water and on offshore banks are under-utilized.

3/ Only a small proportion of the estimated 275,000 tons for Central and South America would be reef species given the extensive areas of soft bottom off Colombia and Venezuela

The use of an average catch rate to estimate potential yield for the entire region area obscures differences in productivity between different areas. FAO exploratory fishing surveys conducted on insular and continental shelves and offshore banks in the Caribbean during 1967-71 with handlines and traps (Kawaguchi, 1974; Wolf and Chislett, 1974) demonstrated considerable regional variation in catch rates. Handline fishing, conducted primarily in deeper water along shelf edges for snapper with mechanical and electric reels, produced high average catch rates south of Jamaica and between Hispaniola and the Virgin Islands and very low catch rates in the Windward Islands (Table 28). Munro (1974), however, estimated handline catch rates of only 1.0-1.2 kg/line-hour on the shelf slope of Pedro Bank. The highest catch rates were obtained on the northeast coast of South America. Wolf and Chislett (1974) reported moderate catches (7 kg/pot lift) for Z-design traps on the Jamaican Banks, north of Hispaniola and off the coasts of Venezuela, Guyana and Surinam, higher catch rates (20 kg/lift) in the northern Leeward Islands and off French Guiana and low catch rates (2.5 kg/lift) from the Windward Islands. In a later survey in the Bahamas, handline catch rates on the shelf slope averaged 9.1 kg/line-hour (Thompson, 1978), a high figure which casts some doubt on the assumption that per-unit area yields in the Bahamas are low because of reduced primary productivity.

Southeastern U.S.

Powles and Barans (MS) reported a mean density estimate of 2.7 tons/km^2 for trawl caught groundfish in areas of "live bottom" in the South Atlantic Bight. Multiplying this figure by the estimated area of live bottom in the area (6,500 km) produced a biomass estimate of about 18,000 tons. No attempt was made to correct the original density estimate for gear efficiency. Assuming q=0.30 (the value applied to groundfish surveys on "normal" bottom areas), biomass would equal 60,000 tons. Assuming a total mortality rate equal to 0.50, maximum potential yield would therefore be about 15,000 tons.

Huntsman et al. (MS), in the absence of species-specific historical catch and effort data for commercial and recreational fisheries in the South Atlantic Bight, and under the assumption that reef fish populations in that area are not recruitment-limited, summarized published growth and mortality estimates for seven species or species groups (Table 29) and calculated yield-per-recruit curves as a function of fishing mortality. Although growth and age-at-recruitment (t_r) estimates were generally available, natural and fishing mortality rates were not and had to be estimated as a range of values based on the population dynamics of similar species or minimum total mortality rates deduced from catch curves. Despite these assumptions, all models showed a similar response to fishing mortality (F). Yield-per-recruit increased rapidly until F=0.3, after which the rate of increase was minimal. Using the lowest natural mortality (M) estimates for the seven species examined, the models predicted that an average 87% of the maximum Y/R could be taken with F=0.3. Furthermore, for F=0.3, a range of t_r values ranging over a period of three to four years could be utilized without a substantial reduction in Y/R. On the basis of the "best" estimates of actual fishing mortality rates, the authors concluded that most of the available yield was being taken as early as 1974 and that 20-35% increases in yield would be achieved only with extremely high fishing effort and reduced unit efficiency. This study provided the basis for recommending that the total estimated 1977 catch (commercial and recreational) of 7,000 tons of demersal reef species be established as the Total Allowable Catch (South Atlantic FMC, 1978). The 1977 catch included 4,500 tons of snapper and grouper.

Campeche Bank

Standing stock and potential yield estimates for Campeche Bank have been reported by Klima (1976a). Snapper and grouper potentials were estimated from U.S. and Cuban trawl surveys (Table 30) and from a surplus production model fitted to 15 years of catch and effort data for the U.S. snapper fleet (Camber, 1955). Biomass estimates from trawl surveys were highly variable since: (1) fishing was directed towards snapper stocks during the 1958-59 U.S. surveys and towards groundfish stocks in general by the Cubans, and (2) the types of trawl used and the catchability (q) of the same gear were evaluated very differently by different investigators.

Klima reported biomass estimates of 250,000 to 2 million tons for all demersal species on the banks using 2 different catchability coefficients. The lower estimate (250,000 tons) was consistent with

standardization procedures used to deduce density estimates from trawl catch rates in other areas of the Western Central Atlantic (Klima, 1976). The more conservative U.S. snapper/grouper biomass estimates were 136,000 tons (Table 30) and indicated a much higher snapper to grouper ratio. Cuban surveys predicted a snapper/grouper biomass of about 300,000 tons and the average from all surveys was 267,000 tons. 1974-75 Cuban estimates varied by a factor of 2.5 depending on which q estimate was used. Potential yield was estimated from Gulland's yield equation for two values of total mortality (Z = 0.20 and 0.40) and varied from 20,000-40,000 tons for snapper and 8,000-16,000 tons for grouper. These values were very approximate given the crude nature of the biomass estimates and the rather arbitrary values for the total mortality rates.

Camber (1955) fitted a linear surplus production model to 1937-1951 catch/unit effort and effort data for the U.S. snapper fleet. Klima (1976) doubled catch and effort figures to account for Cuban and Mexican activity and predicted a MSY of 4,800 tons of snapper and grouper from the same data. This result was clearly erroneous since the reported Mexican and Cuban catches of grouper alone surpassed 18,000 tons in 1972. No correction was made for changes in fishing power and the data were collected after the fishery had already become well established. Thus, the predicted yield curve was forced through a cluster of points near its maximum point.

Melo (1976) calculated growth and mortality rate estimates for *Epinephelus morio* on Campeche Bank which were used by Klima (1976a) to construct a yield-per-recruit model. Melo estimated a total mortality rate of 0.48 from age composition data and set natural mortality equal to 0.15-0.24. The mean age-at-first capture in 1974 was two years. Using K=0.11 and L_∞= 93 cm, the model predicted, for either value of M, that Y/R could be nearly doubled by increasing t_c to six years. The yield isopleths also showed that Y/R will decrease if fishing mortality increases and t_c does not. On the basis of these results, Klima (1976a) estimated a potential yield of 35,000 tons for red grouper, about twice the observed 1972 catch of 19,000 tons. This estimate seems reasonable since potential yield estimates based on trawl surveys were clearly too low and since the growth and mortality parameters used for *E. morio* were generally within the range used by Huntsman and Manooch to predict Y/R for reef species on the southeast coast of the U.S. (Table 29).

U.S. Gulf of Mexico

Attempts to fit surplus production models to 1965-1974 catch (Table 31) and effort data for the U.S. and Cuban commercial snapper/grouper fisheries and the U.S. recreational fishery (Gulf of Mexico FMC, 1979a) were inconclusive given: (1) the poor effort estimates for the recreational fishery, (2) the difficulty in combining commercial and recreational effort statistics, and (3) the poor fit of the model to a limited range of total effort estimates. Furthermore, total commercial effort estimates ignored the fact that the Cuban fishery is principally a longline fishery, whereas U.S. fishermen use handlines. Effort statistics for the two commercial fleets (Table 32) were based on the number of U.S. fishermen and assumed that each fisherman fished 200 days a year.

Maximum yield estimates were also calculated (Gulf of Mexico FMC, 1979a) from average and maximum catch rates reported from exploited reefs north and south of Jamaica (Munro and Thompson, 1973) and an estimate of the amount of habitable and fishable reef area in the Gulf (3.9×10^4 km^2). Assuming that the higher Jamaican value (3.7 tons/km^2) more closely approximated a stock density estimate and assuming a total mortality rate of 0.50, Ymax estimates ranged from 14,000 to 37,000 tons. Applying an average catch per unit area value of 1 ton/km^2 and 0.1-0.2 tons/km^2 for snapper and grouper (Gulland, 1971) produced a Y_{max} estimate of 39,000 tons of demersal reef species and 4,000-8,000 tons of snapper/grouper.

The estimated U.S. commercial catch from the Gulf of Mexico in recent years has been about 4,000 tons. Recreational landings of reef fish were estimated at 10,000-15,000 tons for 1974 and 1975, respectively (Gulf of Mexico FMC, 1979a; Deuel, unpubl.data). The great majority of these landings were snapper and grouper. The Cuban fleet has not been active in U.S. waters in the last few years. Maximum yield estimates based on biomass figures suggested that the total resource could sustain additional fishing effort, but that snapper and grouper stocks may, in fact, be overexploited. This conclusion is supported by the fact that the average catch/vessel and mean size-at-capture for snapper have declined in recent years (Allen & Tashiro, 1976) even though U.S. commercial landings of snapper have remained stable.

Brazil

An exponential surplus production model has been fitted to 1964-77 catch-per-unit-effort and effort data (Table 27) for the Lutjanus purpureus stock in northern Brazil (Programa de PDP, 1978). Effort was estimated as the number of hook-hours. The predicted yield curve fits the data fairly well (Figure 5) and data were available from the early years of the fishery. Catch-per-unit-effort estimates for the years 1964 and 1965 were very high and were omitted from the regression analysis. MSY was estimated at 5,800 tons and f_{MSY} at 13×10^6 hook-hours. Catch reached a peak of 4,860 tons in 1967 and then remained below 4,000 tons until 1973. Recent catches have been near or have exceeded MSY, but the reported 1977 effort was far greater than the amount predicted to produce MSY.

Table 24

Reported 1970-78 Brazilian landings of reef fish, in '000 tons

Year	Brazilian groupers (Mycteroperca spp.)	Red grouper (Epinephelus morio)	Groupers	Red snapper (Lutjanus purpureus)	Yellowtail snapper (Ocyurus chrysurus)	TOTAL
1970	1.1	3.1	2.1	1.4	2.1	9.8
1971	1.0	3.2	2.4	2.2	2.4	11.2
1972	1.2	3.1	2.6	3.8	3.3	14.0
1973	1.6	2.5	1.7	2.8	3.9	12.5
1974	0.6	1.8	1.0	3.5	2.9	9.8
1975	0.7	2.0	1.4	3.2	3.4	10.7
1976	1.2	1.7	1.5	1.6	2.3	8.3
1977	2.2	4.0	1.9	2.7	4.0	14.8
1978	1.6	4.2	0.6	2.6	4.2	13.2

Source: FAO Yearbooks of Fishery Statistics

Note: Catch figures for red snapper reported by FAO are considerably lower than catch figures in Table 27

Table 25

Total reported 1970-78 U.S. commercial landings of snapper and grouper in statistical area 31, in '000 tons

Year	Groupers	Red Snapper	Other Snappers	TOTAL
1970	3.9	4.1	0.9	8.9
1971	3.7	5.1	0.7	9.5
1972	3.7	4.1	0.8	8.6
1973	3.4	4.0	0.9	8.3
1974	3.6	3.6	0.9	8.1
1975	3.7	3.8	1.1	8.6
1976	4.3	4.1	1.1	9.5
1977	3.2	2.8	1.1	7.1
1978	3.2	2.5	1.2	6.9

Source: FAO Yearbooks of Fishery Statistics

Table 26

Reported annual 1970-78 commercial landings of snapper and grouper from the east coast of Mexico, in '000 tons

Year	Red Grouper (*E. morio*)	Other Groupers	Red Snapper (*L. campechanus*)	Other Snappers*	TOTAL
1970	8.7	0.3	2.3	0.6	11.9
1971	10.3	0.4	2.0	1.2	13.9
1972	13.8	0.4	2.8	1.2	18.2
1973	11.7	0.6	2.3	1.2	15.8
1974	12.9	0.4	2.1	1.1	16.5
1975	11.6	0.4	1.9	1.7	15.6
1976	10.6	0.3	1.5	1.2	13.6
1977	11.3	0.4	2.0	1.3	15.0
1978	11.5	0.5	1.8	1.7	15.5
MEAN	11.4	0.4	2.1	1.2	15.1

Sources: FAO Yearbooks of Fishery Statistics

* *Ocyurus chrysurus*, *Lutjanus synagris* and other Lutjanidae

Table 27

Catch, fishing effort and catch-per-unit-effort for snapper (Lutjanus purpureus) on the north and northeast coasts of Brazil, 1964-1977

Year	Catch (tons)	Fishing effort ('000 hook-hr)	Catch-per-unit-effort (kg/hook-hr)
1964	946	326	2.90
1965	2,870	1,076	2.67
1966	3,523	3,561	0.99
1967	4,862	6,575	0.74
1968	3,440	4,104	0.74
1969	3,004	3,984	0.75
1970	1,912	3,659	0.52
1971	2,170	4,255	0.51
1972	2,414	5,888	0.41
1973	4,261	6,456	0.66
1974	4,943	5,682	0.87
1975	5,861	9,158	0.64
1976	5,686	8,900	0.64
1977	6,569	23,464	0.28

Source: Programa de Pesquisa e Desenvolvimento Pesqueiro do Brasil, 1978

Table 28

Average catch rates calculated from 1967-1970 FAO exploratory handline fishing on the shelf slope in various locations in the Caribbean and South America

Location	Hours fished	Catch rate (kg/line-hr)*
South coast of Jamaica and offshore banks	1,605	7.0
Hispaniola to Virgin Islands	412	6.7
Leeward Islands	488	5.4
Windward Islands	266	0.7
Northeast coast of South America	567	8.7
TOTAL:	3,460	5.9

Source: Kawaguchi (1974)

* Originally calculated as weighted mean catch per line equalized to 10 fishing hours/day

Table 29

Instantaneous growth and natural mortality rate estimates for reef fish species in the southeastern U.S.

Species	Growth K	Natural mortality M	Methods
Pagrus pagrus (red porgy)	0.10	0.20-0.35	Higher M estimated from catch curves, lower M inferred from M/K ratio for similar species
Rhomboplites aurorubens (vermillion snapper)	0.20	0.20-0.40	M inferred from age and growth estimates
Haemulon plumieri (white grunt)	0.11	0.37-0.57	Higher M estimated from catch curves, lower M inferred from growth rate
Lutjanus campechanus (red snapper)	0.09-0.33	0.20	Higher K estimate unsatisfactory, lower K for *L. purpureus*. M based on lower K estimate
Centropristis striata (black sea bass)	0.09-0.22	0.30-0.50	Higher K estimate preferable, M estimated from higher K value
Epinephelus morio (red grouper)	0.11-0.17	0.15-0.24	M estimated from catch curves
Mycteroperca microlepis (gag)	0.12	0.20-0.35	M estimated from age and growth estimates, lower M value more likely

Source: Various authors, summarized in Huntsman *et al.* (MS)

Table 30

Standing stock and potential yield estimates of snapper, grouper and other demersal species on Campeche Bank, based on U.S. and Cuban trawl surveys, in '000 tons

Species	U.S. Survey 1/ (1958-1959)	Average Cuban Surveys (1964-1975) 2/	Average All Surveys
Standing Stock			
Snapper	122	215	191
Grouper	14	97	76
Other 3/	117	789	534
Total:	253	1,101	801
Potential Yield 4/			
Snapper	12-24	22-44	19-38
Grouper	1.5-3.0	10-20	8-16
Other	12-24	80-160	54-108
Total:	25-50	110-220	80-160

Source: Klima (1976a)

1/ q = 0.68

2/ Surveys conducted in 1964-72 and 1974-75. Estimates for 1964-72 from Sauskan and Olaechea (1975). Estimates for 1974-75 based on q=0.68 and by adjusting SRT-M trawl (23 m headrope) catch rates to Bacaladero trawl (32 m headrope) catch rates when Bacaladero q=1.0

3/ Includes grunts, porgies and other groundfish species

4/ Calculated from Y_{max}=0.5 ZB, where Z=0.2 and 0.4, and B=exploited biomass

Table 31

Estimated catch data for commercial and recreational Gulf of Mexico reef fisheries, 1965-1974 (in tons)

YEAR	U.S. COMMERCIAL			CUBAN COMMER-CIAL 1/	U.S. RECREATIONAL			TOTAL GULF		
	Grouper	Snapper	All reef fish		Grouper	Snapper	All reef fish	Grouper	Snapper	All reef fish 2/
1965	3.1	1.6	4.7	0.9	7.2	11.4	18.7	11.2	13.0	24.2
1966	2.9	1.2	4.1	1.2	6.8	10.8	16.0	10.9	11.9	21.3
1967	2.4	1.0	3.5	1.5	6.8	9.9	14.1	10.6	10.8	19.1
1968	2.6	1.1	3.8	1.5	7.0	8.8	12.5	11.1	9.9	17.8
1969	3.0	1.1	4.2	1.4	7.2	7.6	11.0	11.6	8.7	16.6
1970	2.8	1.1	4.0	2.6	7.6	6.5	10.0	13.1	7.5	16.5
1971	2.9	1.1	3.7	1.5	7.7	5.2	9.2	11.8	6.3	14.4
1972	2.6	1.5	4.2	2.2	7.8	4.5	9.3	12.6	6.0	15.8
1973	2.0	1.1	3.3	2.0	7.8	4.0	10.0	11.8	5.1	16.3
1974	2.4	1.6	4.1	1.9	7.8	3.8	10.5	12.1	5.3	16.5

Source: Gulf of Mexico Fishery Management Council, 1979a

1/ Assumed to be all grouper

2/ Rows are not necessarily additive since "all reef fish" includes all snappers, all groupers, and other reef fish caught incidentally to the directed fishery

Table 32

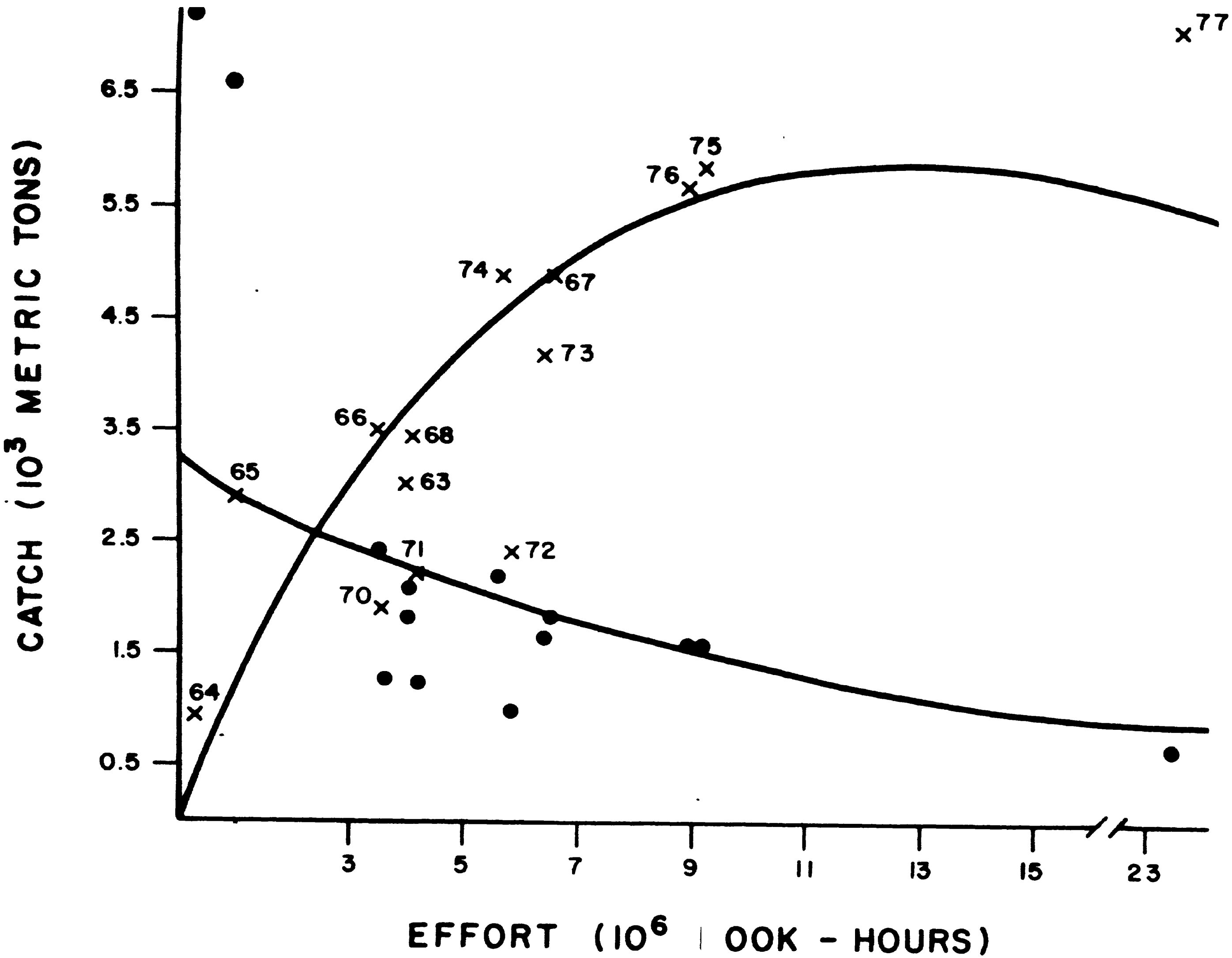
Estimated U.S. and Cuban commercial fishing effort, in '000 handline-days, for the Gulf of Mexico reef fishery, 1965-1974

YEAR	U.S. COMMERCIAL 1/	CUBAN COMMERCIAL 2/
1965	440	81
1966	395	114
1967	369	162
1968	315	127
1969	300	105
1970	261	156
1971	298	186
1972	317	166
1973	325	197
1974	341	158

Source: Gulf of Mexico Fishery Management Council, 1979a

1/ Estimated as number of fishermen x 200 days per fisherman

2/ Total U.S. and Cuban commercial effort = Total commercial catch/U.S. catch-per-unit-effort



5 Exponential regression of 1966-1977 CPUE versus ef ort for the snapper (Lutjanus ›us) hook and line fishery of northern Brazil and the predicted yield curve. 1964 and 1965 data are shown, but were omitted from the analysis (Source: Pr grama PDP do Brasil, 1978)

CHAPTER 5: COASTAL PELAGICS

This group has been loosely defined to include species which inhabit coastal waters of continental or island shelves. Most species school in near-surface or surface waters during at least part of their life cycle. One sub-group, composed of clupeid and small carangid species, is characterized by small size, short life spans, and planktivorous feeding habits. These species are preyed upon by larger fish, birds and marine mammals and generally migrate to some extent in coastal waters. A second sub-group includes larger, longer-lived pelagic predators such as the mackerels (Scomberomorus spp.), and bluefish which migrate long distances.

With the possible exception of the mackerels, all the coastal pelagic stocks in the WECAFC area are under-utilized. Except for menhaden (see Chapter 6), the pelagic resources represent the largest potential for increased exploitation in the Western Central Atlantic. Bullis et al. (1971) speculated that the total pelagic biomass in the WECAFC area could be as high as 10 million tons, and Gulland (1971) estimated a potential yield of 2.5 to 3.2 million tons. These estimates cannot be verified, however, until a great deal more information is available upon which to determine stock identities and base estimates of resource potential for individual stocks. Aside from some biomass estimates for pelagic stocks in the eastern Gulf of Mexico, and yield estimates for mackerel in U.S. and Mexican waters, very little specific information exists.

Assuming that substantial pelagic resources do exist in the region, it may not be practical to harvest them until such time as suitable gear is available and/or the market demand improves. Increased utilization of the smaller, more abundant, species requires canning or the production of fish meal and oil. The failure of Soviet vessels to develop a viable pelagic fishery in the Western Central Atlantic in the 1960s implies that large concentrations of fish were not found (Reintjes, 1979a).

A major problem which hinders the evaluation of pelagic resources in the WECAFC area is the lack of reliable catch statistics. Reported landings of mullet, jacks, Spanish sardine, thread herring, Spanish mackerel and various clupeids and anchovies averaged 118,600 tons between 1970 and 1978 and reached 151,000 tons in 1972 (Table 4). Reported 1978 landings were only 94,500 tons. Reintjes (1979) has noted that only ten WECAFC countries reported landings of any clupeid or carangid species in 1976 and estimated that less than 10% of the total catch was being reported. If this is true, actual catches of these stocks may be as high as 1.0 to 1.5 million tons.

Spanish sardine (Sardinella anchovia = aurita) are abundant along the Gulf coast of the U.S. and Mexico (Reintjes, 1979), but there is no directed fishery for them. A small U.S. bait fishery landed 1,000 tons in 1978. Mexico reported landings exceeding 1,000 tons in 1976 and 1977 and foreign fleets (Poland, U.S.S.R.) reported annual catches of 3,000-4,000 tons from area 31 in 1975 and 1976 (FAO, 1979). Aside from menhaden, the major directed pelagic fishery in the area is for Spanish sardine in northeastern Venezuela. A second species (S. brasiliensis) has been reported, but separate catch statistics are not recorded. Schools are harvested with haul seines within 5-10 miles from shore by a fleet of small, motorized vessels. Small quantities of Atlantic thread herring (Opisthonema oglinum) and anchoveta (Centengraulis edentulus) are caught by the same gear. Until 1965, over 80% of the catch was from the Gulf of Cariaco, but since then the fishery has expanded to other coastal areas (Griffiths & Simpson, 1972). Reported sardine landings averaged about 42,000 tons between 1961 and 1978 with a record high of 55,000 tons in 1972 and a low of 24,300 tons in 1974 (Table 4). Most of the catch is canned, and some is converted into fish meal. The distribution and seasonal occurrence of sardines is apparently related to the upwelling of colder water as equatorial currents enter the Caribbean. Reliable catch and effort data for this fishery do not exist. With the exception of poor harvests in 1974 and 1978, reported landings have been extremely stable in this fishery in recent years.

Griffiths & Simpson (1972) reported that Spanish sardine probably reach a maximum age of five years and are recruited to the fishery in May at a length of 14 cm, the size corresponding to one-year-old fish. Most of the catch consisted of fish between one and three years of age. Sexual maturity was apparently first attained at some length less than 14 cm. Spawning intensity was highest in the early and late months of the year.

Atlantic thread herring (Opisthonema oglinum) are currently harvested as an incidental species in the U.S. menhaden fisheries and the Venezuelan sardine fishery. Thread herring landings ranged from

1,000 to 4,000 tons a year in Venezuela between 1975 and 1978 and from 700 to 8,000 tons in the U.S. during the same period (FAO, 1979). Cuba has also reported landings in recent years (2,400 tons in 1978). Total reported landings in statistical area 31 averaged 7,300 tons from 1974 to 1978, but Reintjes (1979) estimated that the total catch in the WECAFC region is between 30 and 50 thousand tons. Atlantic thread herring and bumper (Chloroscombrus chrysurus) are the principal species caught by the coastal fishery of northeastern Brazil. Fifteen thousand tons of thread herring were landed by three vessels during a short-lived attempt to develop a commercial purse-seine fishery in Florida in 1967-68.

Reported commercial landings of mullet (Mugil spp.) in area 31 were 25,600 tons in 1978 (Table 4). The U.S. accounted for 56% of all 1978 landings, followed by Mexico (19%) and Venezuela (19%). The principal reported species was Mugil cephalus. A few Brazilian mullet (Mugil brasiliensis) were reported from Venezuela and Colombia. 29,000 tons of mullet were landed in Brazil in 1978, but the proportion that was harvested north of 10°S latitude was unknown. Paiva et al. (1971) reported an average annual production of 5,300 tons of mullet from northern Brazil in 1960-68, about a quarter of the total reported Brazilian catch in those years. Deuel (unpublished data) estimated a 1975 recreational catch of 3,100 tons in U.S. waters in the WECAFC area.

Of the many species of jacks (Carangidae) which are exploited in the region, catch statistics are reported for moonfish (Selene setapinnis), blue runner (Caranx crysos), jacks (Caranx spp.), pompano (Trachinotus spp.), amberjacks (Seriola spp.), bigeye scad (Selar crumenophthalmus) and butterfish (Peprilus spp.). Most of the reported catch in area 31 (10,900 tons a year in 1976, 1977 and 1978) was composed of undifferentiated Caranx species, bigeye scad and moonfish. 6,750 tons of Caranx species were reported from Brazil in 1978. U.S. recreational landings of jacks in 1975 were estimated to be 5,250 tons (Deuel, unpublished data).

Reintjes (1979) concluded that at least 28 species of scads, jacks and related fishes are present in the WECAFC area and divided them into two groups. The first group was composed of smaller schooling fishes which feed on planktonic crustaceans and larval fish. These species are attracted to light and artificial structures, can be harvested with a variety of nets and can be marketed as fresh or frozen fish. The principal species in this group are:

Round scad	Decapterus punctatus
Rough scad	Trachurus lathmai
Bigeye scad	Selar crumenophthalmus
Atlantic bumber	Chloroscombrus chrysurus
Mackerel scad	Decapterus macarellus
Redtail scad	Decapterus tabl

The second group included larger, more solitary piscivorous fishes which are not as abundant and are principally harvested by trolling, handlining and nets. They are:

Rainbow runner	Elagatis bipinnulata
Blue runner	Caranx crysos
Crevalle jack	Caranx hippos
Yellow jack	Caranx bartholomaei
Horse-eye jack	Caranx latus
Bar jack	Caranx ruber
Amberjacks	Seriola spp.

Other coastal pelagic resources which are exploited in the Western Central Atlantic include the mackerels (mostly Scomberomorus species), bluefish (Pomatomus saltatrix), dolphin (Coryphaena hippurus) and cobia (Rachycentron canadum). Reported commercial landings of mackerel in statistical area 31 were 20,000 tons in 1978 (FAO, 1979). An additional 2,500 tons of Scomberomorus were reported from Brazil in 1978, of which an unknown proportion were caught north of 10°S latitude. The majority of the Scomberomorus harvested by commercial fleets in the WECAFC area were Spanish mackerel (S. maculatus) landed in Mexico, the U.S., Venezuela and Trinidad. King mackerel (S. cavalla) were also landed in the U.S., Mexico and Venezuela. A recent taxonomic revision of this genus (Collette & Russo, 1979) has identified a new species (S. brasiliensis) which replaces S. maculatus along

the continental margin from Yucatan to $30^{o}S$ latitude on the Brazilian coast, but reported catch statistics do not distinguish between the two species. A fourth species, S. regalis, is limited to the Caribbean islands.

Mackerels are intensively fished by U.S. recreational fishermen in the southeastern states and the Gulf of Mexico. Catch statistics were extremely variable, largely reflecting the imprecise nature of the methodologies which have been used to estimate catch. Estimates for king mackerel ranged from 28,800 tons in 1970 (Deuel, 1973) to 5,500 tons in 1975 (Deuel, unpublished data) and for Spanish mackerel from 10,300 tons in 1970 to 4,600 tons in 1975.

Bluefish (Pomatomus saltatrix) are highly migratory and are distributed throughout the region. Reported 1978 landings in area 31 were only 2,200 tons, mostly from the U.S. while 11,000 tons were reported for the entire Brazilian coast (FAO, 1979). This species supports a substantial recreational fishery in the U.S. Total U.S. recreational catch in the WECAFC region was estimated at 4,000 tons in 1975 (Deuel, unpublished data). Reported landings of dolphin (Coryphaena hippurus) in area 31 were 1,600 tons in 1977. Total Brazilian landings reached 4,800 tons in 1978 and U.S. recreational landings were estimated at 3,500 tons in 1975. Catch statistics for cobia (Rachycentron canadum) were available from Mexico (340 tons in 1978) and the U.S. recreational fishery (1,230 tons in 1975).

Assessments

Standing stock estimates for demersal and pelagic species in the eastern Gulf of Mexico (west coast of Florida) were based on egg and larval surveys conducted in 1971-1974. Clupeid larvae accounted for 20% of all larvae collected and nearly half of the larvae which were identified to species belonged to four species of Clupeidae (Houde et al., 1979). The two most common species were Atlantic thread herring and Spanish sardine. Clupeid larvae were especially abundant in shallower water (< 50 m). Biomass estimates (Table 33) were calculated from mean egg and larval densities and fecundity estimates and varied widely between years. The variation in annual abundance of Spanish sardine larvae was too great to permit a reliable standing stock estimate, but biomass was believed to exceed 200,000 tons. Standing stocks for each of the three clupeid species and the round scad were in the 100,000-700,000 tons range. The total biomass of pelagic fishes in the survey area was estimated to be between 1.5 and 3.0 million tons. A range of potential yield estimates was calculated from biomass estimates for each of five species (Table 34) using Gulland's yield equation for unexploited populations and assuming natural mortality rates of 0.4 and 1.0.

Yield-per-recruit models have been developed for king mackerel (Scomberomorus cavalla) and Spanish mackerel (S. maculatus) stocks in U.S. waters (Gulf of Mexico and South Atlantic FMCs, 1979). A single assessment was performed for each species. Tagging studies have suggested that separate stocks of king mackerel may inhabit the Atlantic and Gulf coasts (Williams & Sutherland, 1979). The same may be true of Spanish mackerel. King mackerel inhabit coastal waters from the Gulf of Maine to Rio de Janeiro, Brazil, including the Gulf of Mexico and the Caribbean. Spanish mackerel are limited to more nearshore waters and range from Cape Cod to Miami and in the Gulf of Mexico from Florida to Yucatan. Both species undergo fairly extensive migrations in response to seasonal changes in water temperature. Migration are both north-south and onshore-offshore. Spanish mackerel and smaller king mackerel form schools of similar-sized individuals. These schools are often composed of both species.

King mackerel are large fish commonly reaching standard lengths greater than one meter. Females grow faster and reach a larger maximum size than males. Beaumariage (1973) developed an age-length key for king mackerel in Florida based on annular otolith marks and reported an age-at-full-recruitment of two to three years (68-78 cm) in the handline fishery and ages three to four (72-82 cm) in the gill-net fishery. Only a few fish older than seven years were represented in the catch data, although fish as old as 14 years have been reported. Major spawning occurs at age four and over in females (82 cm) and at age three and over in males (72 cm). Spawning seasons are protracted with several spawning peaks.

The Y/R assessment for king mackerel was based on combined growth parameter estimates for male and female fish, assuming a 1:1 sex ratio in the exploited population. Growth parameter estimates were $K=0.21$, $L_{\infty}=101$ cm, and $W_{\infty}=9.4$ kg. The calculated W_{∞} was much lower than actual maximum

weight since the growth parameters were estimated from a sample of the exploited population which was not representative of the entire stock. It was not clear why a combined K estimate of 0.21 was selected when Beaumariage (1973) originally reported K=0.21 for female king mackerel and K=0.35 for males. An average total mortality rate of 0.71 was calculated from age-frequency data for the commercial handline fishery given by Beaumariage (1973). Since no direct estimates of M or F were available, M was estimated from minimum and maximum M/K ratio values for two tropical tuna species (Thunnus albacares and Euthynnus pelamis). For K=0.21, the most likely range of M values was 0.3 to 0.6 and the "best" estimate was 0.4. The corresponding values of F were 0.41 to 0.11 and the "best" estimate was 0.31. The maximum age in the exploitable phase (t_c) was placed at eight years and the age-at-first-capture (t_c) ranged from one to two years.

The relationship of Y/R at age t_c to F was calculated for four values of M (0.3, 0.4, 0.5, 0.6) and three t_c values (1.0, 1.5 and 2.0 years). Predicted Y/R curves for king mackerel were very "flat" (Figure 6) so yield at $F_{0.1}$ was selected to define maximum Y/R 5/. MSY was calculated from maximum Y/R by estimating R (the number of annual recruits) from an average population size ($\bar{N}$) when $\bar{N}$ was estimated from the number of fish caught annually in both the recreational and commercial fisheries. This procedure required several simplifying assumptions which seemed to hold true for mackerel stocks. These were: (1) that natural and fishing mortality occur simultaneously; (2) that recruitment is constant from year to year and continuous throughout the fishing season; and (3) that the stock is in equilibrium. If these assumptions are met, the average population size $\bar{N}$ is equal to the number caught (C) divided by the instantaneous fishing mortality rate F. The total number of recruits (R) at t_c is equal to the total mortality rate (Z) times $\bar{N}$. Catch in numbers was calculated from the numbers of king mackerel landed by sports fishermen in 1970 (Deuel, 1973) plus commercial landings (converted to numbers caught on the basis of an estimated mean weight per fish) and from recreational landings estimated from local creel surveys plus commercial landings in 1975. MSY calculated from the 1975 data was 17,000 tons based on the "best estimated of natural mortality (M=0.4) and age-at-first-capture (t_c=1.5 years), with a range of 12,400 to 24,400 tons (Table 35). Two estimates of the 1975 catch were 8,500 and 13,900 tons, depending on which estimate of total recreational catch was used. The present t_c is at or near the value which produces MSY for M=0.4 for the commercial gill-net fishery and has remained the same in recent years since no changes have been made in the mesh size used in the fishery.

Spanish mackerel are smaller fish. Otolith studies (Powell, 1975) revealed maximum theoretical lengths (L_∞) of 64 cm for females and 52 cm for males. Growth rates were slightly different for the two sexes. An age-length key based on otolith studies by Klima (1959) predicted much smaller age I and II fish, but similar maximum size and age estimates. Using Powell's growth predictions, 93% of the commercial and recreational catch sampled in Florida in 1968-1969 was composed of fish age III or younger and 43% were age I fish. The fishery is principally a gill-net fishery and the age composition of the catch can be assumed to have changed very little since the same mesh size has been used. Spanish mackerel spawn repeatedly over a prolonged time period, but in shallower, more nearshore waters than king mackerel.

Assessment of Spanish mackerel stock in the southeastern U.S. and U.S. Gulf of Mexico was based on growth parameter estimates of K=0.47 and L_∞=558 mm obtained by pooling Powell's (1975) length-at-age data for each sex into a single Walford plot of l_{t+1} versus l_t. Powell's length-weight equation was used to estimate W_∞=1.8 kg for the combined data. A 1:1 sex ratio was assumed. Estimates of total mortality from a variety of sources, or from data which from Z could be calculated (Powell, 1975; Klima, 1959 & 1976a; Powell, unpublished data) ranged from 0.71 to 1.25. The "best" estimate was 1.0. The most likely range of M values was determined from the same published values of M/K which were used for estimating M for king mackerel. The most likely values for M varied from 0.50 to 0.80 and for F from 0.20 to 0.50. The maximum exploitable age was set equal to five years.

5/ $F_{0.1}$ is defined as the point at which an increase in F of one unit will produce an increase in Y/R equal to 10% of the increase per unit in Y/R at F values near zero. The Y/R at $F_{0.1}$ is almost as great as at F_{MAX}, but is achieved with much less effort than at F_{MAX}

As was the case for king mackerel, the relations of Y/R to F for a variety of M and t_c values were "flat-topped" curves (Fig. 7). Maximum Y/R values were determined for $F_{0.1}$ instead of F_{MAX} and the point of maximum yield was calculated from maximum Y/R, using 1970 and 1975 estimates of recruitment following the same procedure that was applied to the king mackerel analysis. For the 1975 recruitment estimate and the "best" parameter estimates (M=0.70 and t_c=1.5 years), MSY was 12,400 tons with a range of 6,200 to 22,600 tons (Table 36). The estimated 1975 catch was about 9,500 tons.

The "best" MSY estimates for both king and Spanish mackerel indicated that these stocks were not being over-exploited in U.S. waters in 1975. Given the approximate nature of both assessments, however, and the wide error margin associated with the recreational catch estimates, it is possible that mackerel stocks are being fished at or near MSY, especially if multiple stocks exist which are subjected to variable fishing intensity. The commercial mackerel fisheries are centered in south Florida whereas most of the recreational fishery is located on the west coast of Florida and in the Gulf of Mexico.

Independent evidence suggests that king mackerel yields are approaching MSY. A decline in catch-per-unit-effort has been observed in the commercial handline and gill-net fisheries in south Florida. Mean catch per handline boat dropped from 16.6 tons in 1970 to 5.4 tons in 1975 (South Atlantic & Gulf of Mexico FMCs, 1979) while effort increased from 100 to 300 handline boats and from 12 to 36 gill-net vessels between 1969 and 1976. Catch-per-unit-effort data for the gill-net fishery were not as reliable since effort in this fishery has been more affected in recent years by the increasing use of power rollers, electronic fish finders, monofilament nets and the use of spotter aircraft. There were about 80 gill-net vessels in the fleet, fishing for both king and Spanish mackerel, in 1979. A similar increase in recreational fishing activity was inferred from a mean annual increase of 9.5% in the number of 16-25 foot boats registered in Florida between 1965 and 1975 (South Atlantic & Gulf of Mexico FMCs, 1979). Limited data indicated a decline in the recreational CPUE since the early 1970s. Comparable information for either the commercial or recreational Spanish mackerel fisheries was not available.

Doi & Mendizabal (1979) have assessed Spanish mackerel on the Mexican coast and concluded that present yields (5,000 tons) could be doubled without depleting the stock as long as the age composition remains the same. This analysis was based on a much lower growth rate estimate (K=0.14) determined from otolith studies, but estimated total and natural mortality rates were identical to those used to calculate MSY for the U.S. stocks (Z=0.90; M=0.70). Klima (1976a) calculated Z rates of 1.20 and 0.77 from age-frequency data from the same fishery for 1966-67 and 1973-74. He used growth estimates of K=0.24, L_∞=76 cm, W_∞=2.7 kg, t_c=2 years and M estimates of 0.3 and 0.4 to predict that maximum Y/R could be increased by 10-25% following an increase in t_c to three years and concluded that the stock appeared to be nearly fully exploited.

Table 33

Annual standing stock estimates for coastal pelagic species in the eastern Gulf of Mexico, based on egg and larval surveys

Species	Year	Standing Stock ('000 t)	Source
Etrumeus teres (round herring)	1971-72	718	Houde, 1977
	1972-73	131	Houde, 1977
Opisthonema oglinum (thread herring)	1971	110	Houde, 1977a
	1972	47	Houde, 1977a
	1973	372	Houde, 1977a
Harengula jaguana (scaled sardine)	1971	16	Houde, 1977b
	1972	93	Houde, 1977b
	1973	330	Houde, 1977b
Decapterus punctatus (round scad)	1971	84	Leak, 1977
	1972	249	Leak, 1977
	1973	147	Leak, 1977
Trachurus lathmai (rough scad)	1971-72	21	Leak, 1977
	1972-73	28	Leak, 1977

Table 34

Maximum potential yield estimates* for five pelagic species in the eastern Gulf of Mexico, based on 1971-1974 average biomass estimates, in '000 tons

Species	Y_{max} when M=0.40	Y_{max} when M=1.0
Round herring	50	250
Thread herring	60	120
Scaled sardine	46	92
Round scad	70	85
Rough scad	12	14
Total :	240	560

Sources: Houde, 1977, 1977a, 1977b; and Leak, 1977

* $Y_{max} = 0.5 \, M \, B_0$, when B_0 = average biomass estimated from egg and larval surveys

Table 35

Estimates of upper, lower and "best" MSY for king mackerel stock in U.S. waters of the Western Central Atlantic and corresponding catch estimates, in '000 tons

	Based on 1970 estimates of recreational catch 1/	Based on 1975 estimates of recreational catch	Parameter value estimates M	t_c
Likely MSY Upper Bound	55.4	24.4 2/	0.5	1.5
"Best" MSY Estimate	38.5	17.0 2/	0.4	1.5
Likely MSY Lower Bound	28.2	12.4 2/	0.3	1.0
Corresponding Estimates of Total Recreational and Commercial Catch	32.0	13.9 2/ 8.5 3/		

Adapted from South Atlantic and Gulf of Mexico FMCs, 1979
1/ From Deuel (1973)
2/ Based on adjusted estimates for 1975, from creel surveys
3/ Adjusted estimates for 1975, based on Deuel (unpubl.data)

Table 36

Estimates of upper, lower and "best" MSY for Spanish mackerel stock in U.S. waters of the Western Central Atlantic and corresponding catch estimates, in '000 tons

	Based on 1970 estimates of recreational catch 1/	Based on 1975 estimates of recreational catch	Parameter value estimates M	t_c
Likely MSY Upper Bound	37.6	22.6 2/	0.8	2.0
"Best" MSY Estimate	20.7	12.4 2/	0.7	1.5
Likely MSY Lower Bound	10.3	6.2 2/	0.5	1.0
Corresponding Estimates of Total Recreational and Commercial Catch	16.4	9.3 2/ 9.8 3/		

Adapted from South Atlantic and Gulf of Mexico FMCs, 1979
1/ From Deuel (1973).
2/ Based on adjusted estimates for 1975, from creel surveys
3/ Adjusted estimates for 1975, based on Deuel (unpubl.data)

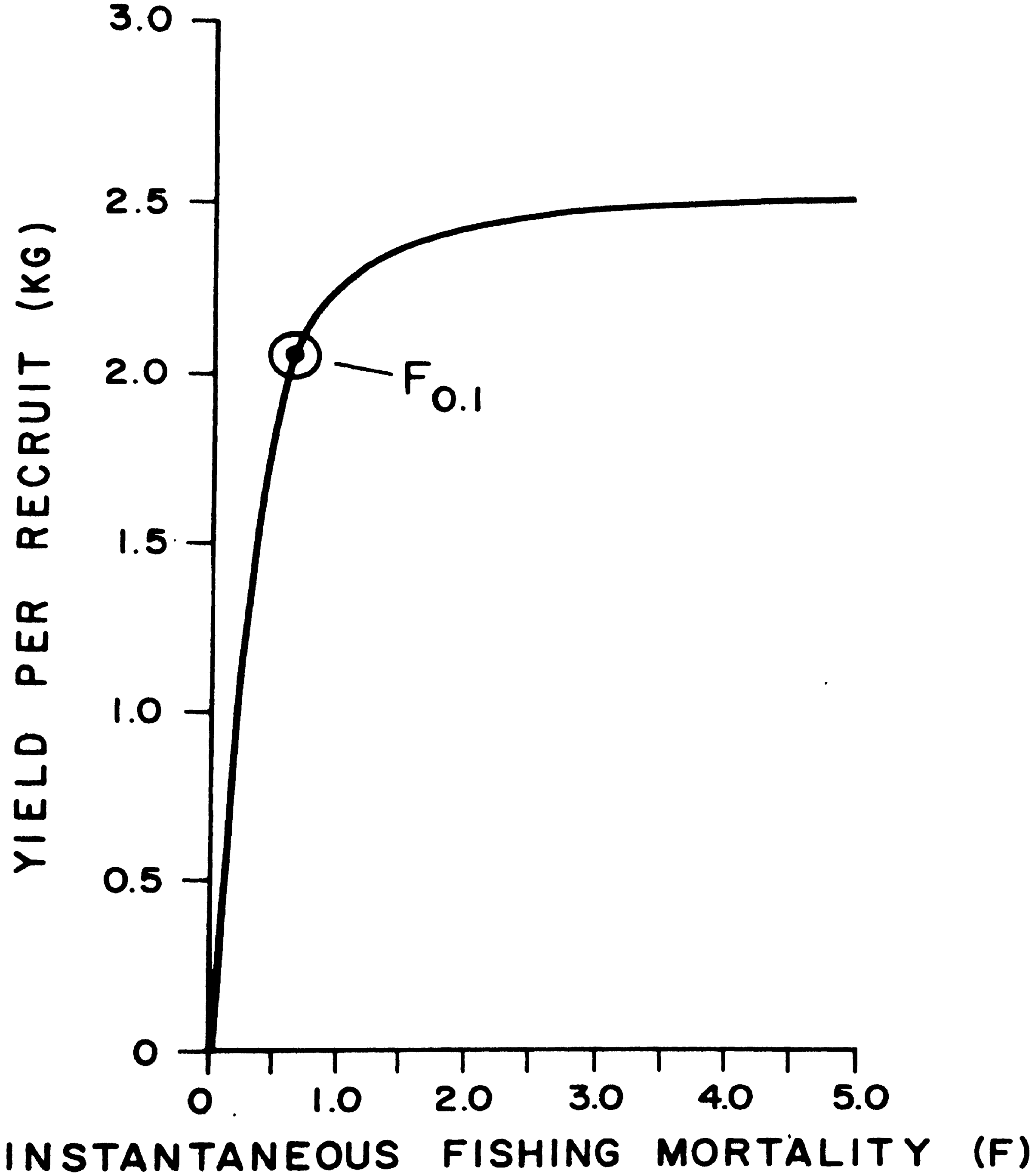


Figure 6 Predicted yield-per-recruit (Y/R) curve as a function of fishing mortality (F) for king mackerel (Scomberomorus cavalla) in the U.S. Western Central Atlantic, based on "best" estimates of age-at-first-capture and natural mortality showing Y/R at $F_{0.1}$ (Source: Gulf of Mexico FMC, 1979)

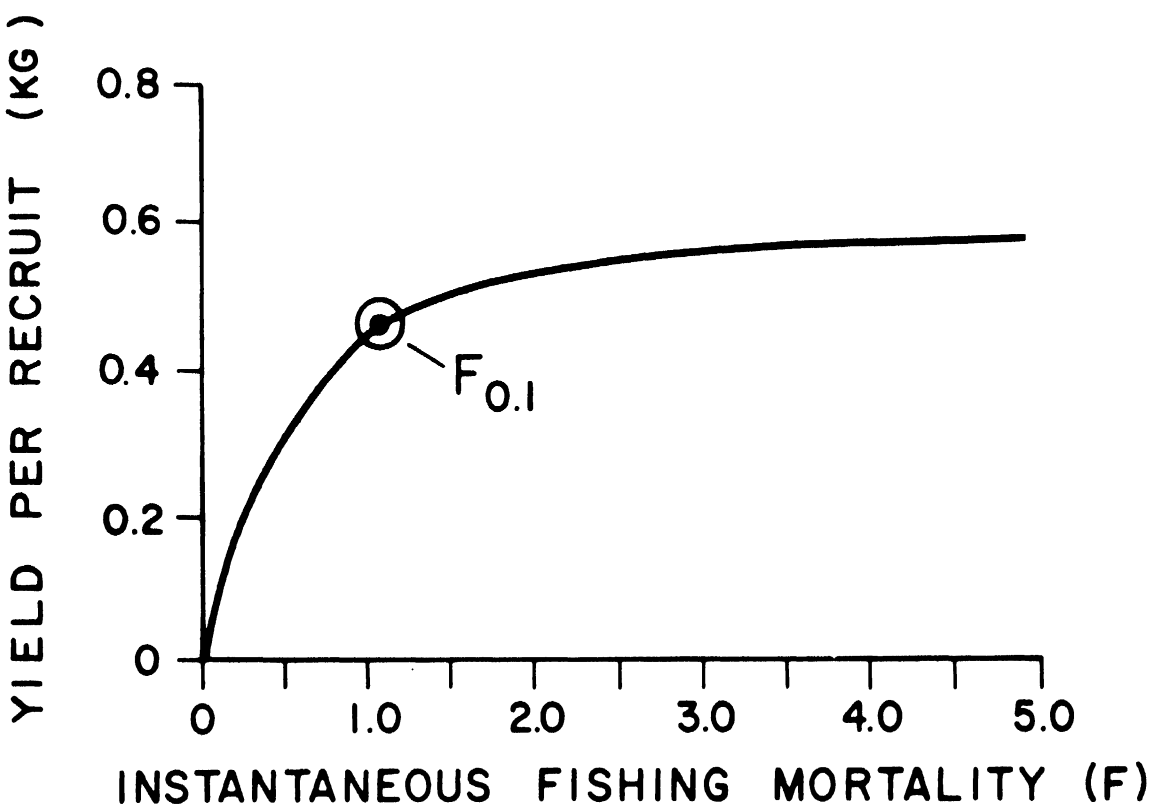


Figure 7 Predicted yield-per-recruit (Y/R) curve as a function of fishing mortality (F) for Spanish mackerel (Scomberomorus maculatus) in the U.S. Western Central Atlantic, based on "best" estimates of age-at-first-capture and natural mortality showing Y/R at $F_{0.1}$ (Source: Gulf of Mexico FMC, 1979)

CHAPTER 6 : MENHADEN

In terms of weight of landings, the menhaden fishery is by far the most important fishery in the Western Central Atlantic. Total landings of 914,000 tons in 1978 accounted for 46% of the total reported catch in the region. Two species make up the bulk of the catch, Brevoortia tyrannus in the Atlantic and Brevoortia patronus in the Gulf of Mexico. The fishery is carried out exclusively in U.S. waters. Both species have been harvested since the mid-1800s, but the Atlantic fishery was dominant throughout the 1940s and 1950s until catch declined dramatically in 1963 (Figure 8). Both fisheries began to expand rapidly following World War II with the introduction of more modern and efficient vessels and harvest techniques. Menhaden are harvested with purse-seines and are reduced to fish meal and oil.

Menhaden are pelagic planktivorous fishes which form dense schools in nearshore coastal waters, making them extremely vulnerable to modern purse seine fishing. Brevoortia tyrannus are distributed along the east coast of the U.S. from Nova Scotia to Florida. This is a longer-lived species than its Gulf of Mexico counterpart. The maximum age is ten years, although the maximum exploited age before the resource "crashed" in 1963 was seven years (NMFS, 1979). Very few fish older than age IV are currently exploited. Brevoortia patronus reach five years of age, but more than 90% of the current landings are composed of one to two-year-old fish. Both species spawn offshore and the larvae are transported to nursery grounds in inshore bays, sounds and estuaries. Juvenile Gulf menhaden migrate offshore after 5-10 months and some are recruited to the fishery in the late summer of their first year (NMFS, 1979). In addition to an inshore-offshore movement, tagging studies (Dryfoos, Cheek and Kroger, 1973; Nicholson, 1978) have shown that Atlantic menhaden also migrate extensively along the coast in response to seasonal temperature changes and that the population is a single unit stock throughout its range. In the summer, the population is stratified by age and size along the entire coast with younger, smaller fish more abundant south of Cape Hatteras. Older fish migrate south from New England in the late summer, arriving at Cape Hatteras in November and south of the Cape in January. Tagging of Gulf menhaden (Pristas et al., 1976) has revealed very little east-west movement of adults, but there is no evidence to suggest that more than one stock exists in the Gulf. Populations of both species are subject to wide variations in annual and seasonal abundance owing largely to variable recruitment. Other species of menhaden which are harvested by menhaden vessels in the Gulf are B. smithi and B. gunteri. Two other species of menhaden, B. aurea and B. pectinata, occur in northeastern Brazil (Reintjes, 1979).

Landings of Atlantic menhaden increased steadily through the 1950s to a high record of 712,000 tons in 1956 and then declined abruptly after 1962, reaching a record low of 161,000 tons in 1969 (Figure 8). The fishery recovered somewhat in the 1970s. Annual landings have averaged 315,000 tons in the last ten years (1970-79). Atlantic menhaden are harvested principally north of Cape Hatteras, i.e. outside of the WECAFC area. Between 1975 and 1978, 23% of the total catch was taken south of Cape Hatteras (FAO, 1979). The fishery "crashed" in 1963 following a combination of heavy fishing mortality and poor recruitment. High catches in the late 1950s were sustained by strong 1955, 1956 and 1958 year classes (Schaaf & Huntsman, 1972).

Landings of Gulf menhaden have generally increased from <10,000 tons in 1946 to records high of about 800,000 tons in 1978 and 1979, despite periodic declines in production in the late 1950s, late 1960s and mid-1970s (Figure 9). Unlike the Atlantic menhaden, the Gulf stock has not yet shown signs of a large-scale reduction in abundance. Such a reduction may, however, be imminent if this fishery follows the same pattern as in the Atlantic. Fluctuations in catch have been more apparent in the Gulf since there are fewer age classes in the population.

Atlantic menhaden

Two yield models have been fitted to historical catch and effort data from the Atlantic fishery. Schaaf & Huntsman (1972) estimated MSY and the amount of fishing efort which produces MSY (f_{MSY}) from 1955-1969 data with a linear surplus production model, adjusting effort (the number of vessel-weeks) for changes in efficiency through 1969. Schaaf (1975) restandardized effort relative to a 1971 vessel-week and updated the original yield estimates through 1973. The same model has been fitted by

the author to 1955-1979 catch and effort data, using unadjusted effort data since 1971 (Table 37 and Figure 10). Current MSY estimates (556,000 tons) were only slightly lower than the original prediction (Table 38).

Schaaf & Huntsman (1972) also estimated growth and mortality rates and applied a dynamic pool model to estimating MSY for Atlantic menhaden. Recruitment was estimated from a Ricker spawner/recruit model. Parameter values were $K=0.39$, $W_\infty=830$ g, $M=0.37$, $t_L=8$ years and a range of t_c and F values. Annual total mortality rates (Z) were calculated from catch and effort data for the years 1955-1964 and, with a constant natural mortality, annual fishing mortality rates were also obtained. These estimates, together with age-specific catch estimates (ages II-V) provided data for calculating the annual expectation of death from fishing for the spawning stock (u_s) and the spawning stock size (S) of fishes age III and older, i.e.

$$u_s = F\,(1-e^{-Z})/Z \qquad (2)$$

and

$$S_j = \left(\sum_{i=s}^{k} C_{ij}\right) / u_s \qquad (3)$$

where,

S_j = spawning stock in year j

C_{ij} = catch in numbers of age i fish in year j

Recruitment (R) was assumed to begin at age I and be complete by age II. Since the maximum exploitation rates 6/ (u_{max}) for one-year-old fish averaged 2/3 of u_{max} for ages II through V, only 2/3 of F was applied to obtain u for age I fish, so that:

$$R_{ij} = C_{ij} / u_r \qquad (4)$$

where,

R_{ij} = recruitment in year j

$u_r = 2/3\, u_s = 2F\,(1-e^{-Z}) / 3Z$

A Ricker stock-recruitment model was fitted to annual S and R estimates and a maximum recruitment of 2.9 billion recruits was predicted for a spawning stock size of 654 million fish (Figure 11).

Yield-per-recruit analysis was performed for four t values (1.5, 2.0, 2.5 and 3.0 years) and showed that $F_{MSY}=0.80$ when $t_c=1.5$ years, the recruitment age which prevailed during the 1950s and 1960s. Observed annual F rates exceeded 0.80, often by substantial margins, during the years of high production. The stock-recruitment model allowed prediction of future population structures for different levels of fishing. A simulation programme incorporated the S/R model, $M=0.37$, selected values of F and weight-at-age information and, assuming average recruitment for given stock sizes, predicted a MSY of 380,000 tons when $F_{MSY}=0.80$. This assessment has not been up-dated.

The difference in maximum yield predicted by the two models was attributed primarily to the unusually abundant 1955, 1956 and 1958 year classes, which supported the high 1955-1962 catches. The dynamic pool model probably provided a more reliable estimate since it was based on the average recruitment expected from a given spawning stock. The problem with this model is that F_{MSY} cannot immediately be associated with a given fishing effort given the changes in fishing power which have taken place in the fishery.

6/ Maximum exploitation rates were defined as: $U_{ij} = C_{ij} / \sum^{k} C_{ij}$

where,

u_{ij} = the maximum exploitation rate for age i fish in year j

C_{ij} = the catch of age i fish in year j

k = the maximum age represented in the landings

$\sum^{k} C_{ij}$ = the virtual population

Assuming that current catches of 350,000 tons a year are acceptable (since they do not exceed MSY), higher catches could presumably be taken if effort were reduced to take advantage of future large year classes by maintaining a spawning stock size of optimum size. Nelson et al. (1977) estimated recruit survival from age composition data for the years 1955-1971 and concluded that the maintenance of an optimum spawning stock during the period of heavy exploitation would have increased annual yields during the subsequent 1967-1971 period by an average 231,000 tons. After a temporary reduction in effort in the early 1970s, current effort has returned to levels which exceed that which corresponds to the maximum mortality rate which the population can sustain without eventually declining to zero (the biological break-even point or BBEP). In addition, F_{MSY} would produce a population in which 17% of the catch would be composed of fish age III or older. In 1972, following three years of reduced effort, only 11% of the catch was age III or older (NMFS, 1979). Age II fish accounted for more of the total landings in 1979 than in any recent year.

Nelson et al. (1977) modified the original spawner-recruit model of Schaaf & Huntsman (1972) and developed an environmental model for predicting recruit survival which accounted for 84% of the variation in survival. The most significant variable in the model was the onshore transport of eggs and larvae from offshore spawning grounds to estuarine nursery grounds. Surplus yield was calculated under conditions which would maintain four spawning ages (ages III-VI) in the population. Based on estimated survival rates during 1955-1971 and the optimum spawning stock size predicted by the Ricker function, allowable catch averaged 419,000 tons a year with extremes of 227,000 to 633,000 tons, depending on the size of the year classes in the population each year. The "best" allowable estimate was only slightly higher than the MSY predicted by the dynamic pool model. The environmental model developed by Nelson et al. could provide the basis for predicting allowable catches of menhaden for individual areas along the Atlantic coast.

Gulf menhaden

A linear surplus production model was originally fitted to 1946-1970 catch and effort data (Table 39) for the Gulf menhaden stock by Chapoton (1972) and on two subsequent occasions by Schaaf (1975) and Klima (1976). Maximum equilibrium yield and corresponding effort estimates (Table 40) have been updated by the author with data through 1979. Effort was measured as the number of vessel-ton-weeks and was not standardized since larger vessels were assumed to be more efficient. Recent catches (800,000 tons) were far in excess of the MSY of 550,000 tons predicted by the model, although the amount of fishing effort in recent years has not exceeded f_{MSY}. The model, however, did not adequately fit the observed data given the wide oscillations in catch which have occurred since 1957 and the absence of data points on the right-hand side of the derived equilibrium yield curve (Figure 12). The addition of 1975-1979 data increased the MSY estimate by 60,000 tons over the 1946-1974 estimate. Even more significantly, elimination of the single anomalous 1946 data point resulted in a MSY estimate of 625,000 tons and f_{MSY} of 700,000 vessel-ton-weeks. Yield estimates for the Gulf menhaden fishery are too variable to be acceptable for management purposes.

Attempts have been made to forecast annual catches of Atlantic and Gulf menhaden from an empirical multiple regression equation which requires historical catch and effort data and effort predictions for the upcoming year (Schaaf et al., 1975). The percent variation between back-calculated and actual catches for the Atlantic fishery (1956-1972) was 85% and for the Gulf fishery (1946-1972) it was 86% (Figures 13,14). Forecasts since 1972 have not accurately predicted abrupt changes in catch such as took place in the Gulf fishery in 1978 and 1979. In both cases, actual catch fell outside the 80% confidence limits for the predicted catch. In general, this model is of limited utility since it fails to account for variations in year class strength which, in many years, have a greater effect on catch than does fishing effort.

Table 37

Catch, observed and adjusted fishing effort and catch-per-unit-effort in the Atlantic menhaden fishery, 1955-1979

Year	Catch ('000 t)	Observed effort (vessel-weeks)	Adjusted effort (1971 vessel-weeks)	Catch/effort 1/ (tons/ vessel-weeks)
1955	641	2748	630	1.02
1956	712	2878	760	0.94
1957	603	2775	800	0.75
1958	510	2343	510	1.00
1959	659	2847	655	1.01
1960	530	2097	560	0.95
1961	576	2371	480	1.20
1962	538	2351	840	0.64
1963	347	2331	1000	0.35
1964	269	1807	1110	0.24
1965	273	1805	1230	0.22
1966	220	1386	1110	0.20
1967	194	1316	955	0.20
1968	235	1209	1260	0.19
1969	161	995	990	0.16
1970	259	906	870	0.30
1971	250	897	865	0.29
1972	366	973	-	0.38
1973	347	1099	-	0.36
1974	292	1145	-	0.26
1975	250	1218	-	0.21
1976	340	1163	-	0.29
1977	341	1239	-	0.28
1978	344	1210	-	0.28
1979	360 2/	1250 2/	-	0.29

Sources: National Marine Fisheries Service (1979), and Schaaf (1975)

1/ Effort measured as standard 1971 vessel-weeks through 1971 and as observed effort after 1971

2/ Extrapolated from information through late November, 1979

Table 38

Estimates of maximum sustainable yield (MSY) and the amount of fishing effort corresponding to MSY (f_{MSY}) for the Atlantic menhaden fishery

Model	Years	MSY ('000 t)	f_{MSY} (vessel-weeks)	Source
Surplus production	1955-69	620	1000 1/	Schaaf & Huntsman, 1972
Surplus production	1955-73	560	630 2/	Schaaf, 1975
Surplus production	1955-79	556	678 3/	This report
Dynamic pool	1955-69	380	-	Schaaf & Huntsman, 1972
Environmental	1955-71	419	-	Nelson et al., 1977

1/ Standardized for 1969 vessel-weeks
2/ Standardized for 1971 vessel-weeks
3/ Range of 277,000-633,000 tons depending on age composition of the spawning population

Table 39

Catch, fishing effort and catch-per-unit-effort in the Gulf menhaden fishery, 1946-1979

Year	Catch ('000 tons)	Effort ('000 vessel-ton-weeks)	Catch/Effort (tons/'000 vessel-ton-weeks)
1946	9	2	3.71
1947	34	21	1.61
1948	75	41	1.83
1949	107	66	1.62
1950	147	82	1.79
1951	155	94	1.64
1952	227	113	2.00
1953	196	105	1.87
1954	181	113	1.60
1955	213	123	1.74
1956	244	155	1.57
1957	159	155	1.03
1958	196	203	0.97
1959	326	206	1.58
1960	377	212	1.78
1961	456	242	1.89
1962	479	289	1.66
1963	438	277	1.58
1964	408	273	1.49
1965	408	273	1.49
1966	358	382	0.94
1967	316	405	0.78
1968	372	382	0.97
1969	522	411	1.27
1970	546	400	1.36
1971	728	473	1.54
1972	502	448	1.12
1973	486	426	1.14
1974	579	485	1.19
1975	543	536	1.01
1976	561	576	0.97
1977	447	533	0.84
1978	820	574	1.43
1979	778	534	1.46

Source: National Marine Fisheries Service, 1979

Table 40

Estimates of maximum sustainable yield (MSY) and the amount of fishing effort corresponding to MSY (f_{MSY}) for the Gulf of Mexico menhaden fishery

Model	Years	MSY ('000 tons)	Effort ('000 vessel-ton-weeks)	Source
Surplus production	1946-70	430	408	Chapoton, 1972
Surplus production	1946-72	478	460	Schaaf, 1975
Surplus production	1946-74	490	-	Klima, 1976
Surplus production	1946-79	551	554	This report

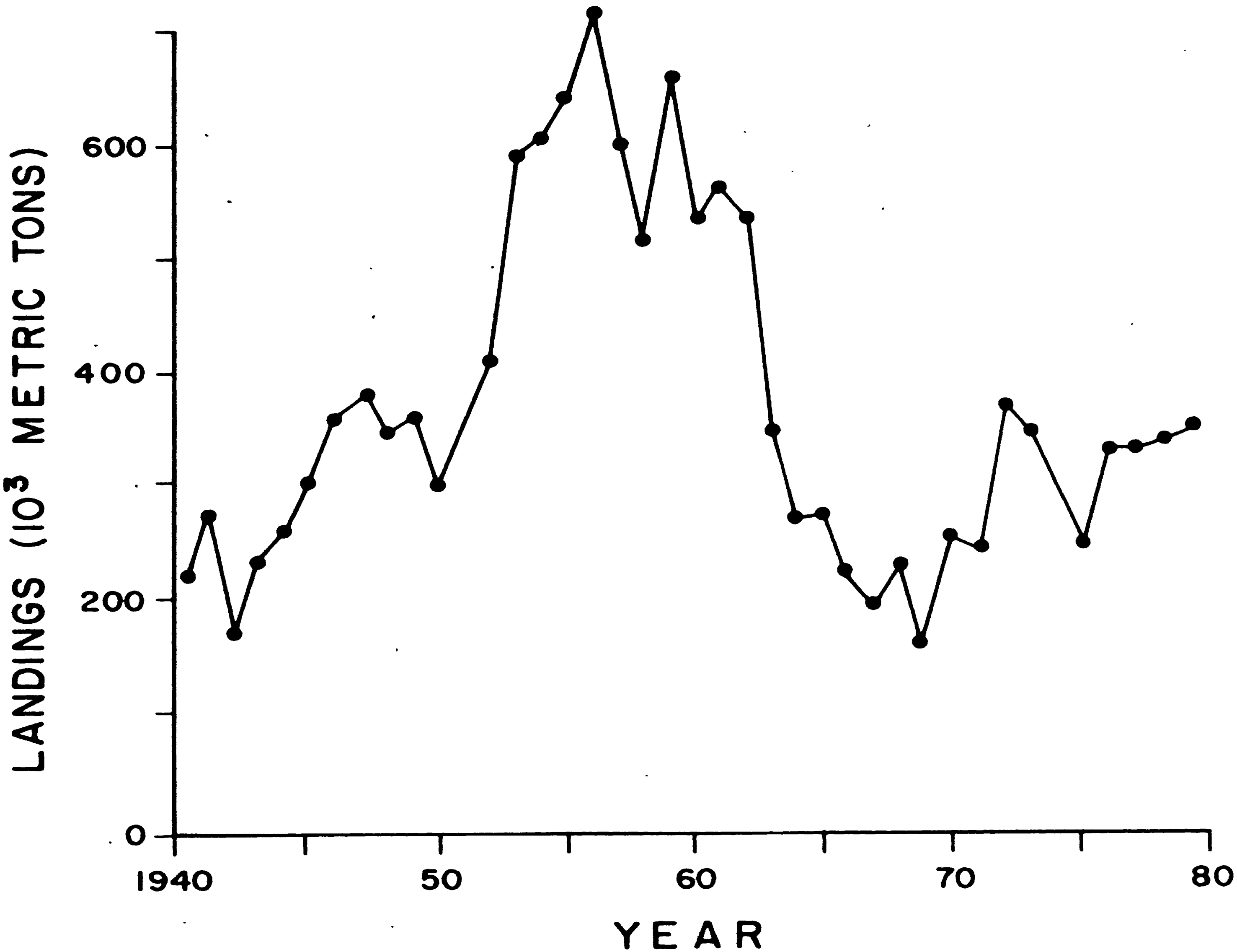


Figure 8 Annual U.S. Atlantic menhaden (*Brevoortia tyrannus*) purse-seine landings, 1940-1979 (Source: NMFS, 1979)

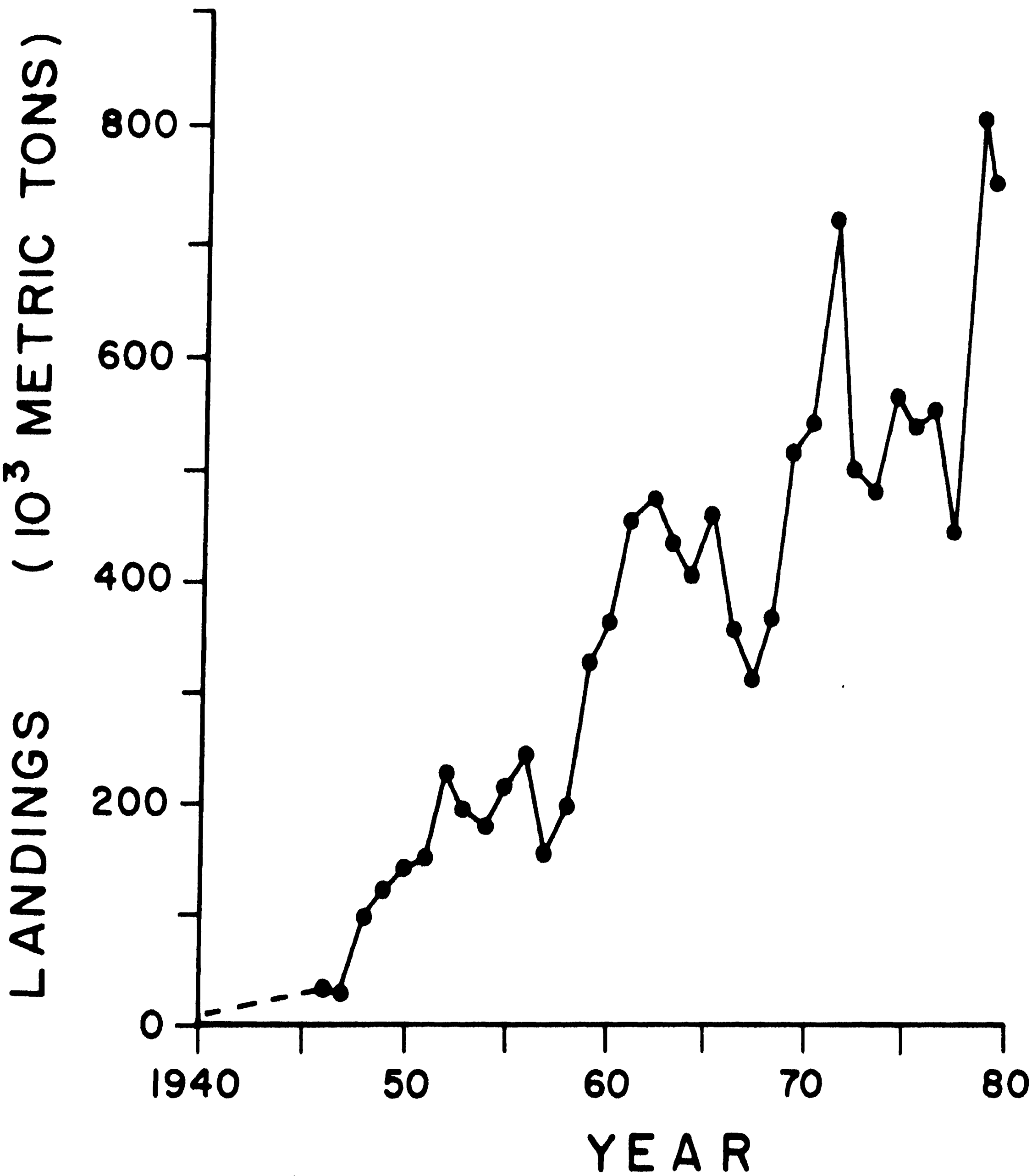
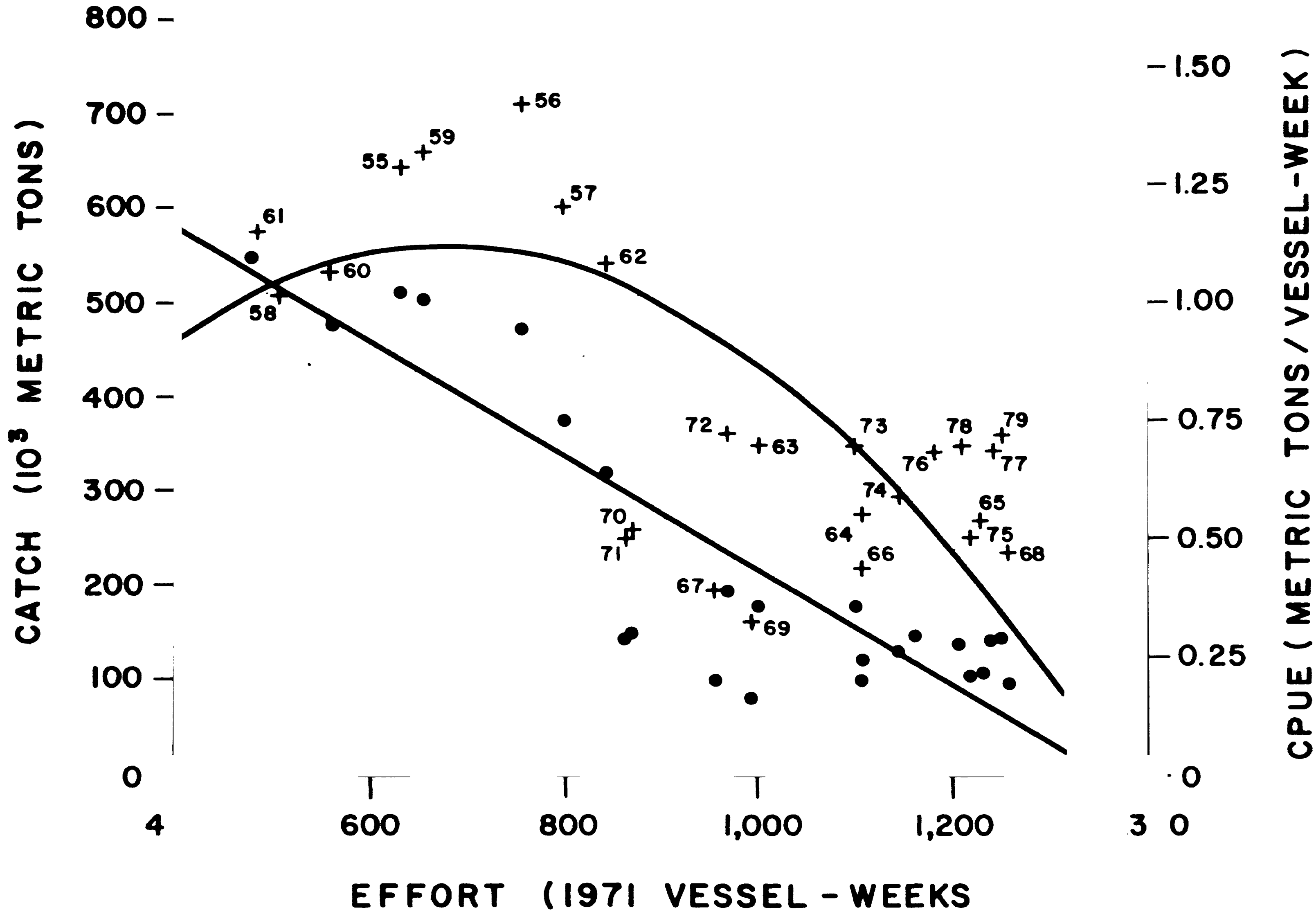


Figure 9 Annual U.S. Gulf menhaden (*Brevoortia patronus*) purse-seine landings, 1946-1979 (Source: NMFS, 1979)



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Catch and effort data from NMFS, 1979 and Schaff, 1975)

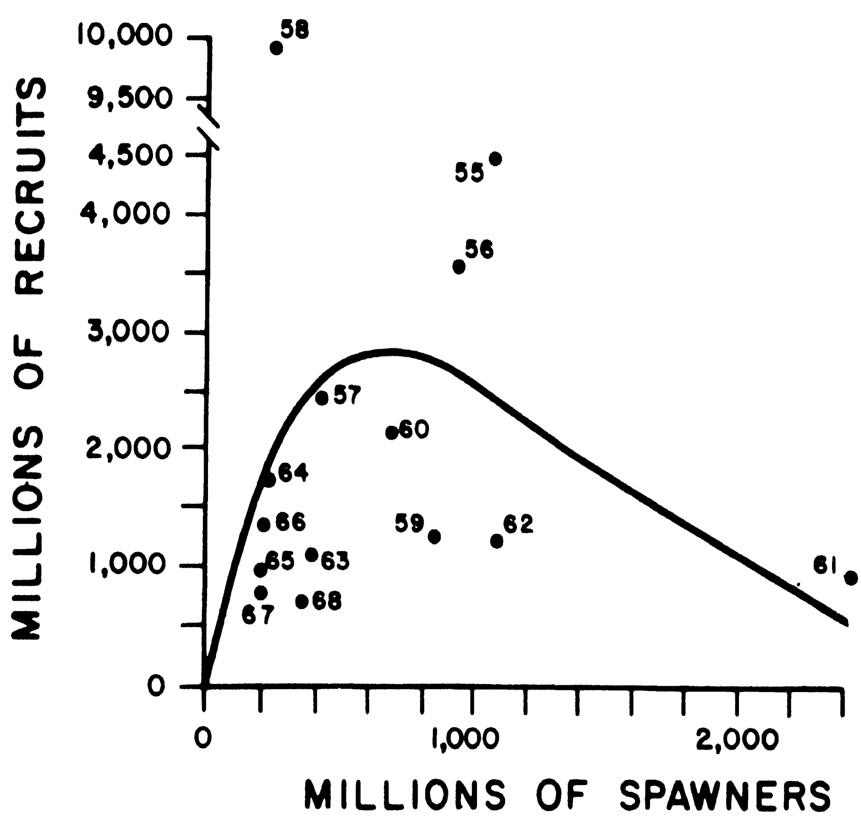


Figure 11 Ricker stock-recruitment model fit to 1955-1968 estimates of numbers of recruits and numbers of spawning Atlantic menhaden (Brevoortia tyrannus) (Source: Schaaf and Huntsman, 1972)

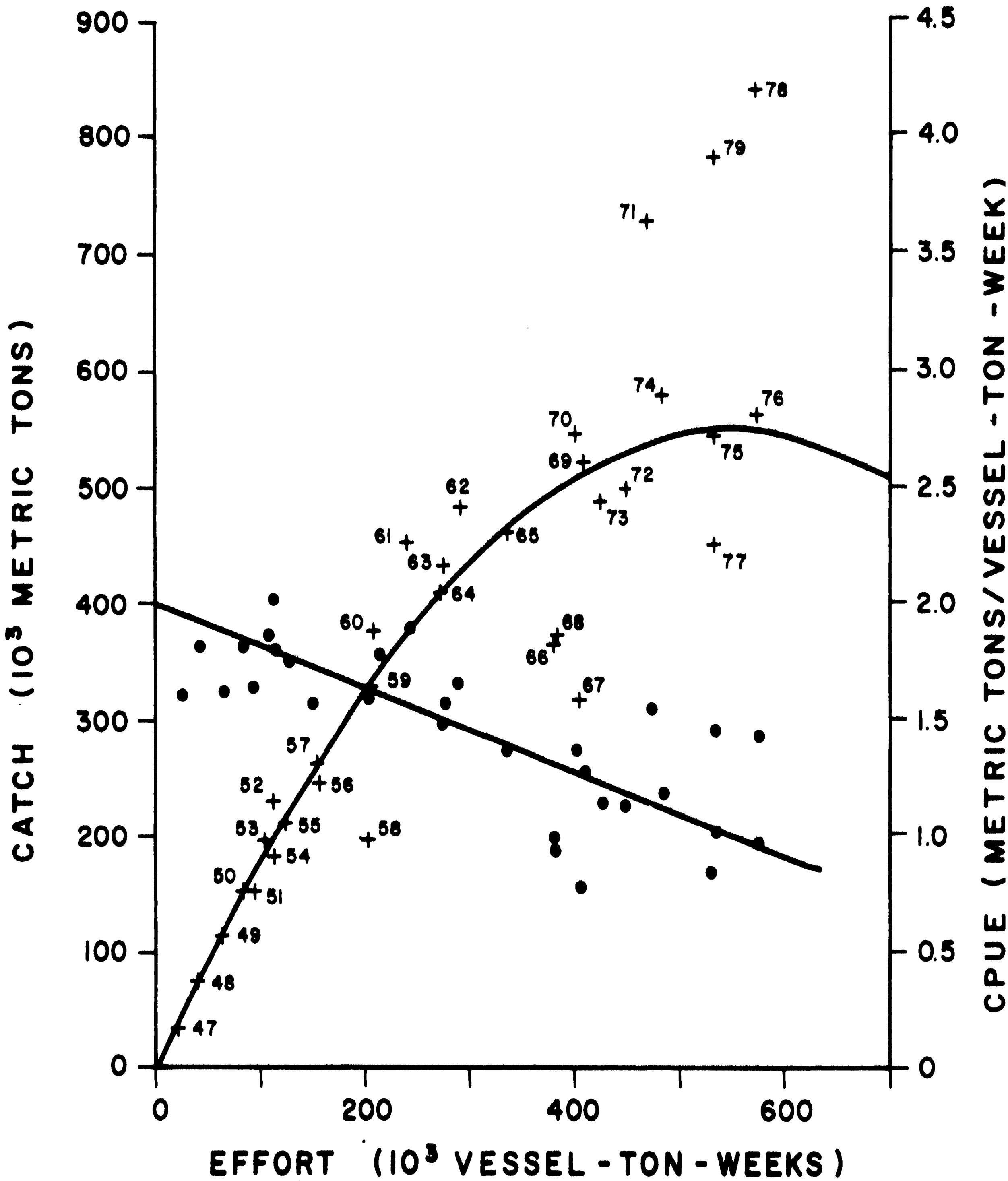


Figure 12 Linear regression of 1947-1979 CPUE versus effort for the U.S. Gulf menhaden (*Brevoortia patronus*) fishery and the predicted yield curve (Source: Catch and effort data from NMFS, 1979)

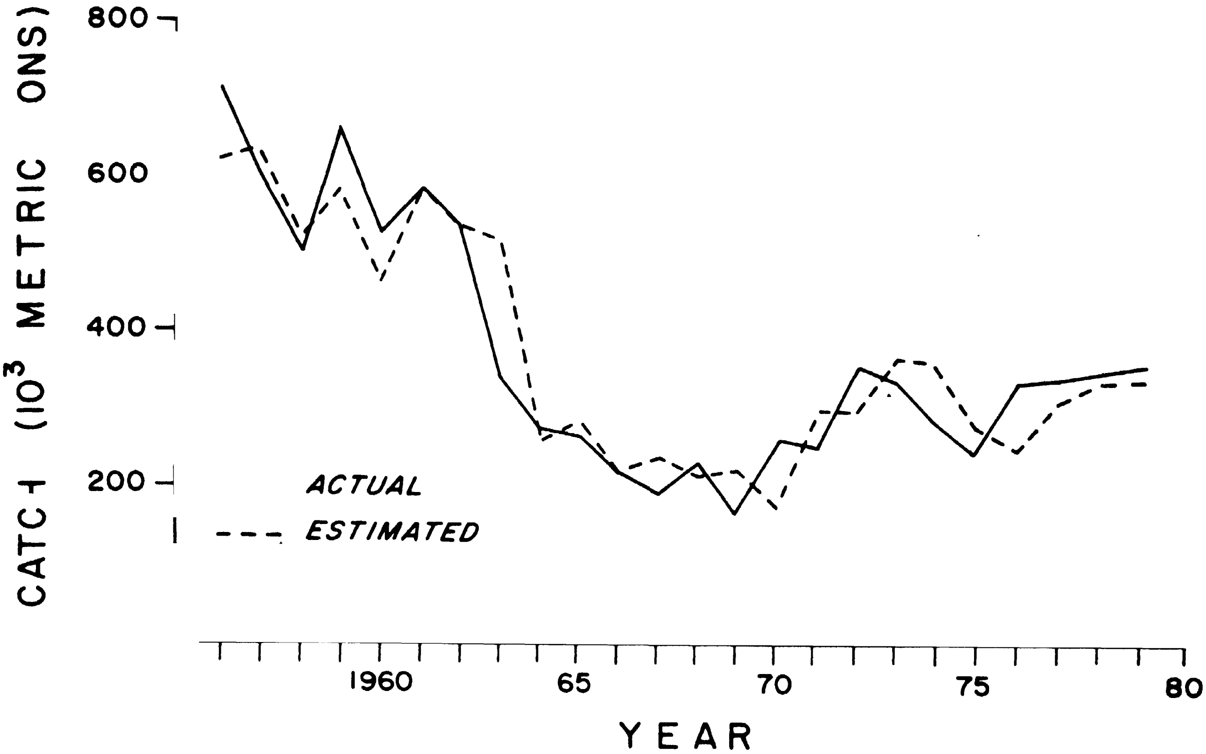


Figure 13 Actual and predicted annual U.S. Atlantic menhaden (Brevoortia tyrannus) purse-seine landings, 1956-1979. Catch was predicted from a multiple regression equation incorporating historical catch and effort data and effort predictions for the upcoming year (Source: Schaaf et al., 1975)

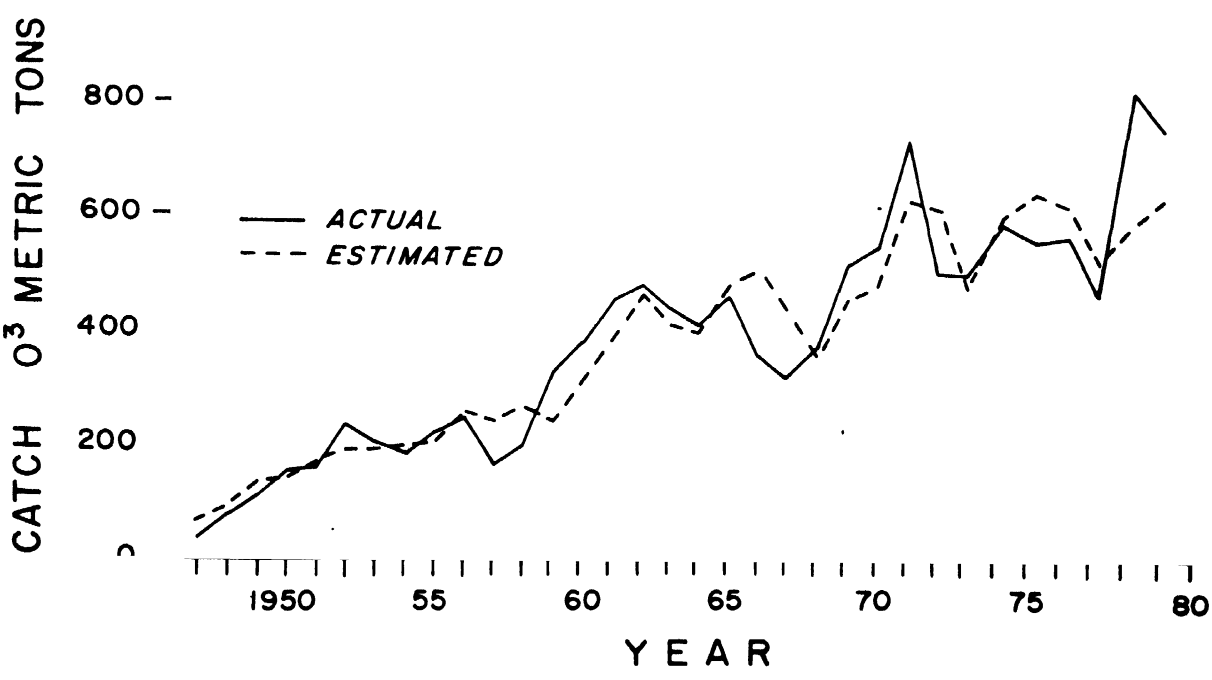


Figure 14 Actual and predicted annual U.S. Gulf menhaden (Brevoortia patronus) purse-seine landings, 1947-1979. Catch was predicted from a multiple regression equation incorporating historical catch and effort data and effort predictions for the upcoming year (Source: Schaaf et al., 1975)

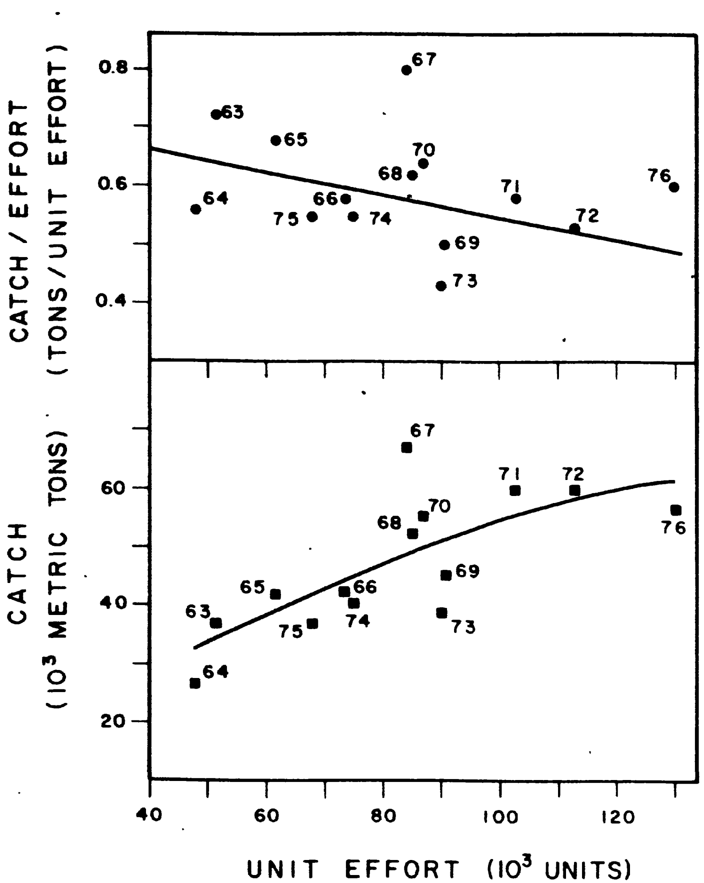


Figure 15

Linear regression of 1963-1976 CPUE versus standardized effort for brown shrimp (Penaeus aztecus) harvested by the U.S. trawl fishery in the U.S. Gulf of Mexico and the predicted yield curve. Catch is expressed as whole weight (Source: Gulf of Mexico FMC, 1980)

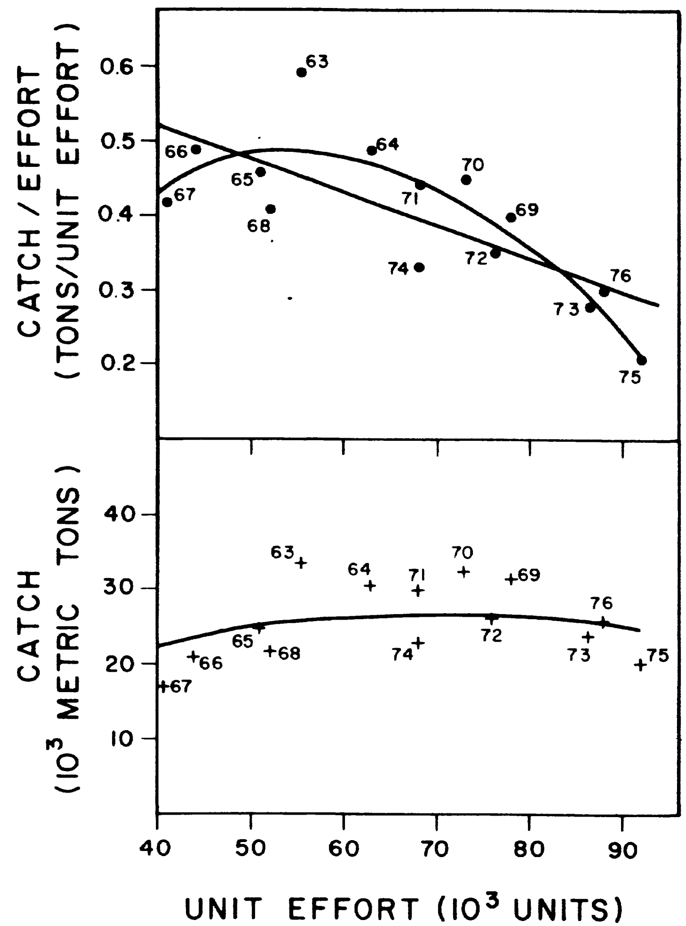


Figure 16

Linear and exponential regression of 1963-1976 CPUE versus standardized effort for white shrimp (Penaeus setiferus) harvested by the U.S. trawl fishery in the U.S. Gulf of Mexico and the predicted yield curve for the linear model. Catch is expressed as whole weight (Source: Gulf of Mexico FMC, 1980)

CHAPTER 7: SHRIMP

From an economic point of view, shrimp resources support the most important fishing industry in the Western Central Atlantic. Reported commercial landings in statistical area 31 were 180,000 tons in 1978 and have averaged 170,000 tons each year since 1970, representing a 70% increase over average landings during 1961-64 (Table 4). In addition, an average 17,000 tons were harvested annually by the industrial fishery in northern Brazil and the Guianas between 1970 and 1978. Recreational and bait fisheries also exploit significant quantities of shrimp; catches of 20,000 tons have been estimated for the U.S. Gulf of Mexico (Gulf of Mexico FMC, 1980), and Paiva et al. (1971) reported almost 8,000 tons a year for artisanal fisheries in northern Brazil between 1960 and 1968 (Table 2). Reported commercial shrimp landings for the entire WECAFC area in recent years have represented 14% of the total world production (FAO, 1979). Over 90% of the reported shrimp catch in the WECAFC area is composed of species which belong to the genus Penaeus (Wise, 1976).

Shrimp are abundant along the continental coasts of the Western Central Atlantic and on the Cuban shelf. Trawl fisheries have developed in trawlable areas with major shrimp concentrations, especially along the northern Gulf of Mexico, the Mexican coast and off the northeast coast of South America. Fisheries in these three areas have accounted for approximately 75% of the total landings in the region in recent years (Wise, 1976). U.S. trawl fisheries have existed in the southeastern states and along the Gulf coast since the early 1900s and expanded rapidly in the 1950s with the introduction of improved fishing gear and larger vessels. The U.S., Mexican and Venezuelan fisheries opened in the late 1940s and early 1950s and an international fishery was initiated off the Guianas and northeast Brazil in the 1960s.

Principal species captured in U.S. and Mexican waters are Penaeus aztecus, Penaeus setiferus and Penaeus duorarum (brown, white and pink shrimp). Brown and pink shrimp are harvested principally in depths of 30-60 m while white shrimp are more abundant in shallower water (< 30 m). P. duorarum is the principal species harvested on Campeche Bank and in southwest Florida, while P. aztecus is the predominant species in the northern Gulf of Mexico. White and brown shrimp account for most of the landings in the southeastern U.S. Along the Central and South American coasts, these three species are replaced by P. schmitti, P. brasiliensis, P. notialis and P. subtilis.

All the penaeid species share similar life histories. Important features are the migration of juvenile shrimp from inshore estuaries to offshore spawning grounds, a short life span (12-18 months), extremely high rates of growth and natural mortality and high fecundity. Growth also varies seasonally. Grant and Griffin (1979) reviewed published growth rate information for brown shrimp in the Gulf of Mexico and reported growth rates of 1.0-1.5 mm/day in the early spring and 1.7-3.3 mm/day during late May. Environmental factors (temperature and salinity) affect the growth and survival of larvae and juveniles during the estuarine phase of the life cycle (Zein-Elden and Griffith, 1969).

Other non-penaeid species comprise <10% of the reported commercial catch in the region. Seabobs (Xiphopenaeus kroyeri) are caught incidentally by the trawl fishery and by artisanal fisheries in shallow coastal waters throughout the region. The small size of this species has limited its market value and production. Rock shrimp (Sicyonia brevirostris) are caught in 20-50 m in northwest Florida and Yucatan, Mexico, and are rapidly gaining market popularity. Royal red shrimp (Pleoticus robustus) are found in deep water (200 m or more) and are the subject of small directed fisheries in eastern and southwest Florida and off the Mississippi River delta. In addition to seabobs, Exhippolystoma oplophoroides and Trachypenaeus similis are harvested by artisanal fisheries in the Amazon River delta (Fischer, 1978).

Lindner (1971) estimated a total shrimp potential of 160,000 to 185,000 tons for the Western Central Atlantic exclusive of the Guianas-Brazil grounds. This estimate was surpassed by reported commercial landings in 1972 (Wise, 1976). Gulland (1971) predicted a maximum potential yield of 40,000 tons for the Guianas-Brazil grounds. Bullis et al. (1971) estimated a much higher potential (400,000 tons for the entire region), but included seabob and other under-utilized species on the northeast coast of South America. All of these estimates are very approximate since they were not based on specific analyses of catch and effort data or vital population statistics.

Stock assessments based on commercial catch and effort data collected over the past 10-20 years indicated maximum sustainable yields equal to or somewhat in excess of average annual catches over the same period (Table 41). Reliable estimates of f_{MSY} were obtained in only a few cases and were not summarized. These assessments were conducted - in most cases - with combined catch and effort data (for all penaeid species) and were based on the assumption that geographically defined unit fisheries harvest separate stocks, an assumption that is clearly not true in some instances. All MSY estimates were based on linear or exponential forms of the surplus production model. Some estimates were more reliable than others. Average U.S. catch data (Table 41) included estimates of recreational and bait fishery harvests and discards.

In addition to the assumptions mentioned above, common problems which hindered the application of surplus production models to observed data were: (1) time-series data were only available for reported commercial catches; (2) data were limited mainly to the apparent peak in the yield curves since they were usually collected after the fishery had already stabilized; (3) total fishing effort estimates were usually obtained by extrapolation from catch and catch-per-unit-effort data obtained from a sample of landings; and (4) no attempts were made to standardize effort data for changes in capture efficiency. The results, nevertheless, suggested a total MSY of about 200,000 tons (excluding recreational and bait fisheries) when maximum observed catches were substituted for unknown MSY estimates (Table 41), i.e. catch and estimated MSY appeared to be very similar.

Perhaps the major disadvantage in using steady-state equilibrium models to assess shrimp resources is the fact that environmental effects on recruitment are ignored. It has long been observed that, once shrimp fisheries have fully developed, catch fluctuates widely from year to year. Moreover, production appears to be independent of effort and the size of the spawning population even when effort is high. Management efforts based on manipulations of catch or effort will be inadequate as long as stock size depends primarily on environmental factors which are assumed to be constant over a given time period. Environmental conditions which affect the arrival of larval and juvenile shrimp in inshore estuarine nursery grounds are believed to be a major factor affecting the subsequent recruitment to the offshore fishery. Shrimp populations are essentially composed of a single year-class and respond very quickly to environmental stimuli.

The following summary represents the current "state-of-the-art" in shrimp assessment as applied to specific unit fisheries in the WECAFC region. All of the assessments have been performed with catch and effort data except in the U.S. Gulf of Mexico where results were also available from a yield-per-recruit analysis, a production function which incorporated environmental variables into yield predictions, and two bioeconomic simulation models. Conclusions based on catch and effort data mean very little unless: (1) catch and effort data are available from the beginning of the fishery, and for individual species; (2) effort can be standardized relative to some reference year; (3) stocks are more clearly delineated; and (4) data from international fisheries are collected on a more uniform basis. Even then, surplus production models may not be adequate for assessing shrimp resources since environmental variables are ignored. Successful yield-per-recruit analyses require reliable parameter estimates and, in order to predict MSY, need some basis on which to predict the number of recruits entering the population each year.

Southeastern U.S.

Three species of shrimp are harvested in nearshore waters, bays and sounds. Pink shrimp are exploited only in North Carolina, brown shrimp are more abundant in North Carolina, and white shrimp in Georgia, South Carolina and Florida. Brown and white shrimp accounted for 95% of the commercial landings in the early 1970s (Eldridge and Goldstein, 1975). Rock shrimp and royal red shrimp are also exploited, primarily in eastern Florida.

Total commercial landings have remained fairly stable during the last 20 years, averaging 11,500 tons (Table 41). Three to five year trends in the abundance of white shrimp have been observed (Anderson, 1970). Eldridge and Goldstein (1975) estimated that recreational landings in the area account for 10-15% of the total catch.

Adequate effort statistics do not exist for this fishery and the only existing stock assessment is for an isolated population of royal red shrimp on the St. Augustine grounds east of Florida. Klima (1976) reported a standing stock of 394 206 tons from 1973-75 trawl surveys, and assuming Z=0.5, a maximum potential yield of 100 tons. Management efforts have focussed on protecting the resources, and maximizing catch and economic yield, and have primarily involved the closing of spawning and nursery grounds during certain times of the year and the enforcement of minimum landing sizes, and/or minimum mesh sizes.

U.S. Gulf of Mexico

The U.S. shrimp fishery in the Gulf of Mexico is by far the most important shrimp fishery in the Western Central Atlantic. White shrimp have been trawled in shallow water since about 1920. Brown and pink shrimp were exploited in greater quantities after the fishery expanded into deeper water in the early 1950s. The number of vessels (> 5 gross tons) increased from 2,600 in 1962 to 4,000 in 1973, while their average size increased from 42 tons to 64 tons (Gulf of Mexico FMC, 1980). There were also 5,000 registered commercial boats in the fishery in 1976. Brown shrimp accounted for 57% of the total reported commercial trawl landings of penaeid species between 1963 and 1976 (Table 42), white shrimp for 31%, and pink shrimp 11%. Total reported landings of penaeid species varied between 68,000 and 97,000 tons during the same period. No historical trends in landings were observed for any of these three species. Pink shrimp are harvested in fairly well-defined grounds in southern and southwest Florida, whereas brown and white shrimp are generally available on most of the shelf area of the Gulf.

Royal red shrimp are harvested by specially-rigged vessels in deep water (300-400 m) off the Mississippi River delta and on the Tortugas grounds in southwestern Florida. Seabobs and rock shrimp are caught incidentally to the penaeid species by the inshore trawl fishery. Seabobs are very small and are retained only when market prices are favourable. Reported commercial landings of royal red shrimp reached 225 tons in 1969 and varied between 93 and 192 tons between 1973 and 1976 (Table 43). Reported seabob landings averaged 1,000 tons between 1963 and 1976. Rock shrimp are harvested primarily in Florida: landings have been reported only since 1972 and averaged 300 tons through 1976.

In addition to the harvest by traditional trawl fisheries, an estimated 20,000 tons of penaeid shrimp may be caught by other fisheries and/or discarded by the trawl fishery (Table 44). The recreational fishery apparently accounts for most of this unreported catch. Bait shrimp are harvested with small trawls in shallow inshore waters. Discarded shrimp are presumably under-sized: minimum size limits vary between 30 and 32 tails/kg in the different states. In addition, some areas are closed during certain times of the year.

Different forms of the Pella and Tomlinson's (1969) generalized stock production (GSP) model (m = 0.5, 1.5, 2.0, 3.0) were fitted to 1963-1976 catch and effort data (Table 42) for each of the three individual penaeid species harvested in the Gulf of Mexico (Gulf of Mexico FMC, 1980). Griffin et al. (1977) derived an empirical equation for estimating "real" fishing effort based on the fishing power of vessels as a function of horsepower and net size 7/. Nominal effort (days fishing) was converted to real effort based on the fishing power of a standard vessel type. Real effort (Table 42) was used as the dependent variable in subsequent yield analyses. The importance of adjusting effort to account for changes in capture efficiency was underscored by Nichols et al. (1978) who reported a 96% increase in adjusted effort between 1962 and 1972 as compared to a 65% increase in the number of days (24 hours) fished.

7/ The relative fishing power (RFP_i) for an individual vessel class i was calculated as:

$$RFP_i = \left[\frac{(HP)_i^{0.1385}\,(FRL)_i^{0.4064}}{(38)^{0.1385}\,(14.6)^{0.4064}}\right]$$

where,

HP_i = average horsepower

FRL_i = total length net footrope in yards

The smallest class of vessel operating in the Gulf from 1963 to 1971 was used as a standard vessel with average horsepower of 38 and average footrope length of 14.6 yards (13.1 m).

The best fits of the predicted yield curves to the 1963-1976 data were obtained for m=2.0 for brown and pink shrimp (Figures 15, 16 and 17). Nevertheless, the Schaefer model (m=2.0) was used to estimate MSY for all three species (Table 45). According to this analysis, the total MSY was 100,000 tons. The average annual catch for all three species during 1963-1979 was 86,900 tons (Table 42), suggesting that the resource was exploited at its full biological potential during 1970-1972 and was over-exploited in 1977 and 1978. Looking at individual species, both white and brown shrimp were exploited considerably below MSY during 1973-1975 and were over-exploited in 1977 and 1978, whereas pink shrimp were over-exploited in 174, 1977 and 1978. Estimates of f_{MSY} were not reliable since catch appeared to depend more on variations in recruitment than on fishing effort. These analyses did not take environmental factors into account and have not been up-dated with post-1976 data.

Klima and Parrack (1978) fitted a surplus production model to combined 1956-1975 catch and effort data (excluding three hurricane years) for the same three species and estimated a MSY of 81,000 tons and a f_{MSY} of 225,000 days. Their MSY estimate is lower and suggests more extreme resource over-exploitation. As was true for the yield predictions for individual species, however, the available data were clustered near the peak of the yield curve (Figure 18) and effort was not standardized for changes in fishing power.

Yield-per-recruit models have also been applied to populations of pink and brown shrimp in the Gulf of Mexico. The results, however, were very different depending largely on the mortality rate estimates which were used. Kutkuhn (1966) and Lindner (1966) produced individual weekly estimates of natural mortality rates of 0.55 and 0.075-0.125 respectively, and fishing mortality rates of 0.96 and 0.125-0.175 respectively, for pink shrimp from tag and recapture studies. Berry (1970) estimated total mortality from age composition data (Table 46). He converted length data to age data using a range of growth rate estimates (K = 0.04-0.07) and different L_∞ estimates for male and female shrimp (175 mm and 205 mm total length). Average weekly fishing mortality (0.09) was estimated by the swept area technique during individual months over a four year period. If, in fact, the lower parameter estimates (Table 46) are more reliable, the model indicates that maximum yield would be attained if pink shrimp were harvested before they reached the legal minimum size of 32 tails/kg, i.e. the resource is currently over-exploited. Use of Y/R models is further complicated by the fact that growth rates not only vary by sex, but also by time of year.

Parrack (Ms.) used sex specific growth parameters, weekly natural mortality rates of 0.01 and 0.02 and Berry's fishing mortality rate for pink shrimp to calculate maximum Y/R for brown shrimp in Texas waters. Yield was maximized at a size equivalent to 10-11 tails/kg (5 months old), i.e. at a size considerably larger than the present size-at-first-capture. These results were reviewed by Klima and Parrack (1978).

Griffin and Beattie (1978) derived a modified Spillman production equation which incorporated environmental variables and predicted an MSY for all species of shrimp caught by Gulf vessels (> 5 gross tons) of 95,000 tons. A multiple regression equation was derived which correlated the commercial catch of brown shrimp to temperature, river discharge and fishing effort. The equation predicted 82% of the annual variance in catch over the period 1963-1975 (Figure 19). For 100,000 days of effort, predicted annual yield varied from 42,000 to 65,000 tons given actual temperature and river discharge variations during that period. Actual catch ranged from 38,000 to 79,000 tons during the same period. Similar predictions have been made for the Louisiana white shrimp fishery. The future maintenance of shrimp resources throughout the region will probably depend more on the availability of suitable estuarine habitat than on management strategies designed to achieve MSY and optimum fishing effort.

Grant and Griffin (1979) developed a bioeconomic model and predicted an average annual yield of brown shrimp in statistical area 18 off the Texas coast (Figure 2) which differed from the observed average 1963-1971 catch by only 4%. Weekly growth varied from K=0.04 to 0.15 and weekly M was set equal to 0.21. Fishing mortality was calculated as a function of days fished, relative fishing power and number and availability of shrimp, which in turn depended on an assumed migration rate of new recruits and the number of shrimp that over-wintered offshore. Model simulations fell into two categories, those representing changes in environmental variables and those representing changes in management variables. Simulations involving environmental changes included arbitrary changes in the recruitment rate, while management changes included changes in fishing effort and fishing seasons. Simulations

dealing with changes in recruitment confirmed the fact that the dynamics of harvesting ultimately depend on environmental conditions which affect recruitment. However, no explicit mechanisms for relating recruitment to environmental variables or the size of the parent stock were described. A doubling in the number of days fished produced approximately twice as much harvest and vice-versa. The model was most sensitive to the asymptotic length of shrimp, although M was also an important factor.

A similar exercise was performed for the pink shrimp population on the Dry Tortugas grounds of southwestern Florida (NMFS, 1979a). The bioeconomic model included sex-specific spring and fall growth rates, and a weekly M of 0.07. Simulation included only that portion of the life span beginning at the size-at-recruitment (equivalent to 260 tails/kg) to fishing grounds between 12 and 50 m depth. A simulated Y/R model predicted that drastic changes in l_c would produce no change in weight yield, but would result in considerable increases in economic yield when fishing effort is kept at low levels. Biological yield/recruit was maximized only at high levels of fishing effort and only when l_c was set at 130 tails/kg, but economic yields were maximized when l =76 tails/kg for a wide range of fishing effort values.

Catch and effort data were compiled for royal red shrimp, rock shrimp and seabobs and GSP models were fitted to data arrayed in CPUE versus effort plots. For royal red shrimp, all models (m = 0.5, 1.5, 2.0, 3.0) produced similar results. The Schaefer model (m=2.0) gave an MSY estimate of 325 tons (whole weight) and 1,290 days fishing for three exploited fishing grounds (eastern Florida, the Dry Tortugas and the Mississippi delta). Current harvests and effort (Table 43) have not yet reached MSY levels. Klima (1976) reported a standing stock of 1,800±670 tons for royal red shrimp on the same three grounds based on trawl surveys and, assuming Z=0.50, a potential yield of 450 tons. Equilibrium models were more suitable for assessing this species since it is longer-lived than the penaeid species and inhabits deep water (180-730 m) where it is largely independent of variations in temperatures and salinity. This species occurs throughout the region and is underutilized. Production could be significantly increased if new fishing grounds are discovered.

Seabob shrimp and rock shrimp are harvested incidentally to other species in the Gulf of Mexico and seabobs are frequently discarded at sea. Thus, catch and effort estimates (Table 43) were unreliable for modelling purposes. An MSY estimate of 850 tons was, nevertheless, estimated from 1972-1976 data for rock shrimp suggesting that through 1976 this species was still underutilized in the Gulf of Mexico. The reported 1979 catch reached 3,300 tons.

Mexico

Three unit shrimp fisheries have been described in the coastal waters of Mexico on a geographical basis (Wise, 1976) corresponding to FAO statistical sub-areas 3.1, 3.2 and 3.3 (Figure 20). The designation of these unit fisheries was purely arbitrary and was not meant to imply that shrimp stocks in these three areas were isolated. Catch and effort data were available for the period 1956-1975 for two of these fisheries (Tampico, Campeche) and for 1965-1975 in the third (Contoy).

Attempts have been made to fit surplus production models to CPUE versus effort data in all three cases (WECAFC, 1978). The resulting MSY estimates were not considered to be very reliable. All three fisheries were international, but U.S. and Cuban vessels have been gradually phased out in recent years, leaving only Mexican vessels. A minimum mesh size of 44.5 mm is currently enforced in all three fisheries. In addition to the industrial trawl fishery, shrimp are also harvested in the coastal lagoons and estuaries by artisanal fisheries, but no catch or effort data were available. Total reported shrimp landings for the Gulf coast of Mexico (29,200 tons according to WECAFC, 1978), however, exceeded Mexican landings from the Tampico and Campeche fisheries by 3,300 tons. No Mexican catch data were available for the Contoy fishery.

1. Tampico Fishery (Area 3.1)

This fishery has been active since the late 1940s, but catch and effort data were only available since 1956 (Table 47). Three phases of exploitation can be distinguished: annual production averaged

10,670 tons in 1957-59, 6,180 tons in 1960-65 and 8,660 tons in 1966-75. The three exploited penaeid species are the same as those harvested in U.S. waters. Brown shrimp account for over 90% of current landings. Effort was measured directly as the number of hours fished by the U.S. fleet, and total effort was estimated by dividing total catch (U.S. and Mexican fleets) by U.S. catch-per-unit-effort. Maximum effort was expended in 1958-59 and in 1974. A plot of CPUE versus total effort showed no trends and thus no MSY estimates were made. Tagging studies conducted by U.S. and Mexico since 1978 indicated a considerable exchange of brown and pink shrimp between Texas and northern Mexico (Baxter et al., 1979), suggesting that stocks in these two areas are continuous.

2. Campeche Fishery (Area 3.2)

This fishery has also been active since the late 1940s. Catch and effort data were available since 1956 (Table 48). Catch-per-unit-effort and total effort have been estimated separately for the U.S. and Mexican fleets. U.S. catch-per-unit-effort estimates have consistently exceeded Mexican estimates, by as much as two times during 1972-1974. Reported catch has been stable since the mid-1950s, averaging 22,700 tons during 1956-1974. A record catch of 28,000 tons was reported in 1972 and CPUE was higher after 1971 than during the previous 16 years. The predominant species is pink shrimp, but brown and white shrimp are also harvested. The proportion of brown shrimp in the catch has been increasing since 1970.

Exponential surplus production models have been fitted to U.S. and Mexican data (Figures 21,22), producing MSY estimates of 22,900 and 24,900 tons, respectively, and suggesting that current production is at or slightly below MSY. However, CPUE data were not compiled before catch stabilized in the mid-1950s and, because of the method used to estimate total effort from catch and CPUE, small sampling errors in determining CPUE could have caused shifts in total effort estimates and produced the apparent relationships between CPUE and effort.

3. Contoy Fishery (Area 3.3)

This is a more recent and much smaller fishery. U.S. and Mexican vessels began trawling operations in this area in the mid-1960s. Cuban vessels entered the fishery in 1969. Catch and effort estimates (Table 49) do not include Mexican or Cuban landings. Total effort was estimated from U.S. CPUE for all species. Spotted pink shrimp (*Penaeus brasiliensis*) accounted for over 95% of all U.S. landings until 1972. Some pink shrimp (*P. duorarum*) are also exploited. Rock shrimp (*Sicyonia brevirostris*) were not reported separately before 1972, but have accounted for a large proportion of the catch since 1972. U.S. catch and CPUE estimates were compiled for all species and separately for spotted pink shrimp (Table 49).

An exponential surplus production model was fitted to 1965-1975 U.S. CPUE and effort estimates for all species and for *P. brasiliensis* separately. The results (MSY=1,600 tons for all species, and MSY= 1,300 tons for *P. brasiliensis*) suggested that the U.S. catch had already reached these levels, but the observed data points were fairly widely dispersed about the predicted yield curves (Figures 23,24). Given the recent shift to rock shrimp in this area, assessments based on all species were of little value. Furthermore, catch and effort data were not available for the Mexican and Cuban fleets so that the published MSY estimates do not apply to the entire resource.

Nicaragua (Area 7.3)

This has been an international fishery with participation by U.S., Nicaraguan, Mexican and Honduran vessels, but most vessels now are from Nicaragua and Honduras. Reported commercial landings (Table 50) have been composed primarily of "red shrimp" (*P. duorarum* and *P. brasiliensis*) and white shrimp (*P. schmitti*) with a much smaller percentage of brown shrimp (*P. aztecus*). White and brown shrimp accounted for a greater percentage of the reported landings prior to 1971. Catch data have been compiled since 1958 when the fishery opened, but effort - measured as the number of boats or number of days fishing - was not recorded until 1964. Catches have remained stable between 3,000 and 4,000 tons since 1968. Effort peaked at nearly 12,000 days in 1973 and has been declining since

then, producing slightly improved CPUE in 1975 and 1976 (Table 50). Maximum CPUE was achieved in the late 1960s. Additional quantities of shrimp (especially seabob) are harvested in the coastal lagoons by the artisanal fishery. Total reported landings in 1976 were 4,700 tons (FAO, 1979) as compared to 3,400 tons used for assessment purposes. Total reported landings in 1977 reached 6,000 tons.

An exponential surplus production model has been fitted (WECAFC, 1978) to 1967-76 CPUE and effort data (Table 50) which predicted an MSY equal to 3,800 tons and f_{MSY} equal to 9,500 days, suggesting that yields exceeded MSY in 1969 and 1972 and that effort was excessive in 1973-74. The model fitted the observed data fairly well (Figure 25).

Colombia

The industrial fishery began operations in the area southwest of the Magdalena River in 1969 and later extended to the northeast. Catch and effort (number of days at sea) data were compiled for the period 1972-78 and surplus production models have been fitted (WECAFC, 1979) to the data from both areas (Table 51). Pink shrimp (*Penaeus notialis*) accounted for 95% or more of the industrial catch in both areas in recent areas. White shrimp (*P. schmitti*) are also harvested in both areas and a few pink spotted shrimp (*P. brasiliensis*) are exploited in the northeast. Shrimp are presumably harvested by artisanal coastal fishermen, but no catch data were available.

The relationship between CPUE and effort for the northeast stock was not clear. Increased effort failed to reduce catch-per-unit-effort, and both the low 1978 and high 1974 harvests were produced with the same amount of effort. An MSY estimate based on this analysis was not considered appropritae, but the data did suggest that the fishery in this area could be expanded. There may be some interchange between shrimp stocks in northeast Colombia and the Gulf of Venezuela, although most of the shrimp harvested in the Gulf are white shrimp.

Analysis of data from the southwest coast of Colombia showed a more rapid decline in CPUE with increasing effort. An exponential surplus production model (Figure 26) produced an MSY estimate of about 1,000 tons with 7,000 days effort, suggesting that the fishery reached MSY within three years of opening, and has continued to exploit the resource at the MSY level since 1972.

Venezuela

Catch and effort data were available (WECAFC, 1978) for shrimp fisheries in Lake Maracaibo, the Gulf of Venezuela, northeastern Venezuela and the Atlantic coast of Venezuela. A trawl fishery developed in the Gulf of Venezuela in the late 1940s and early 1950s, and extended to new grounds along the central and eastern coastline in the 1960s, partly in response to reduced yields in the traditional grounds in western Venezuela. Total reported landings for the whole country remained between 5,000 and 6,000 tons in 1975-1977, but dropped to 3,800 tons in 1978 (FAO, 1979).

1. Lake Maracaibo

Small quantities of juvenile white shrimp (*P. schmitti*) are harvested in the northern half of the lake with haul seines and cast nets. Reported catches (WECAFC, 1978) reached 3,000 tons in 1965, declined to less than 1,000 tons in 1966 and 1967, increased to over 1,000 tons in 1970-72, and declined to low levels again in 1974. Effort was measured as the number of seines or skippers and no assessments have been attempted.

2. Gulf of Venezuela

The trawl fishery began operations in 1948 and expanded rapidly in 1964-73. White shrimp and three species of brown shrimp (*P. subtilis*, *P. brasiliensis* and *P. notialis*) are harvested by fleets stationed in Maracaibo and Punto Fijo. The Maracaibo fleet harvests primarily white shrimp while the Punto Fijo fleet harvests brown shrimp. Reported catches of white shrimp exceeded 4,000 tons in 1970,

but declined rapidly to only 425 tons in 1973 (Table 52) and remained low through 1976. Catch-per-unit-effort declined by almost 70% in only three years. Brown shrimp landings exceeded 4,000 tons in 1967 and 1971 and remained below 4,000 tons a year through 1976. CPUE for these species also declined during 1973-76, but not nearly to the extent recorded for white shrimp.

Effort was estimated as the number of days at sea for each fleet by dividing CPUE from a sub-sample of landings into total landings (WECAFC, 1978). An exponential surplus production model was fitted to 1962-76 CPUE versus effort data for brown shrimp, but the data for the two years of peak production (1967 and 1971) did not fall near the predicted values (Figure 27) and the resulting MSY estimate (about 3,000 tons) was very approximate. As was the case for catch and effort data examined in other shrimp fisheries in the WECAFC region, production appeared to bear little relation to the amount of effort expended in either the current year or the previous one, suggesting that variations in recruitment largely determine stock size. Variations in the CPUE/effort relation were even more extreme for the white shrimp data and therefore no MSY estimate was made.

3. Central and Eastern Venezuela

Two small fisheries exist in central and eastern Venezuela, one on the Unare platform and another which operates northeast of Isla Margarita. There were few vessels in either of these fisheries until 1967. Landings and effort have been compiled since 1969 for the Unare fishery (Table 53) and since 1970 for the Isla Margarita fishery (Table 54), but no reliable CPUE/effort relations were found for the Unare fishery (WECAFC, 1978). Effort increased rapidly until 1972, and then stabilized while catches declined from 700 to 400 tons.

Nearly all the shrimp harvested northeast of Isla Margarita are *Penaeus brasiliensis*, but a small quantity of seabob have also been reported. A logarithmic form of the surplus production model fitted 1970-76 data very well and predicted an MSY of 500 tons (WECAFC, 1978). The predicted yield curve (Figure 28) was quite flat, however, and f_{MSY} could not be reliably determined. Effort increased very rapidly in this fishery over just a few years, apparently producing maximum yields as early as 1973.

4. Atlantic Coast of Venezuela

Trawl fisheries are active in the Gulf of Paria (west of Trinidad), south of Trinidad and off Guyana. White shrimp and brown shrimp (*P. notialis* and *P. subtilis*) were of equal importance in both areas during 1973-1975. Venezuelan trawlers began operating in the Gulf of Paria in the mid-1960s, and south of Trinidad in the early 1970s. Landings and effort statistics were available for only a few years (Tables 55,56) and were not analysed for stock assessment purposes. Shrimp stocks south of Trinidad may merge with stocks which are exploited off the Guianas and northern Brazil and are probably exploited by vessels from several countries.

Guianas/Brazil

Shrimp resources off the Guianas and northern Brazil have been exploited since 1959 by vessels from several different countries. The fishery started off Guyana and expanded south into Brazilian waters as far as the Amazon River delta in the mid-1970s. The fleet increased from 100 vessels in 1961 to 645 vessels in 1977 (Table 57) while total effort increased from about 25,000 days at sea in the early 1960s to 100,000 days in 1974. A considerable reduction in the number of vessels followed the expulsion of all foreign vessels from Brazilian waters in 1978.

Maximum landings in excess of 19,000 tons a year were reported in 1968-70, 1973 and 1977 (WECAFC, 1979) 8/. Production increased rapidly in the mid 1960s, averaging 16,500 tons between 1965 and 1969 as compared to only 5,400 tons during 1960-64. Reported landings in recent years have

8/ Landings reported to the 1977 Working Party on Assessment of Shrimp and Lobster Resources (FAO, 1978) were slightly higher, exceeding 20,000 tons in 1968-70 and 21,000 tons in 1973.

increased very little (1970-78 average = 17,200 tons). An additional quantity of shrimp are harvested in nearshore and estuarine waters by artisanal fishermen. Paiva et al. (1971) estimated an average annual production of 7,800 tons from northern Brazil between 1960 and 1968. Most of these were probably seabob. The offshore fishery harvests four penaeid species: Penaeus brasiliensis, which dominated U.S. commercial catches off Guyana, Surinam and western French Guiana; P. subtilis which were most prevalent off eastern French Guiana and Brazil; P. notialis, off Guyana; and P. schmitti, off Guyana, French Guiana and Brazil, primarily in shallow waters (Jones and Dragovich, 1977).

Naidu and Boerema (1972) compiled catch and effort data for individual national fleets for the period 1961-69. Effort was estimated as the average number of vessels fishing each year. Jones and Dragovich (1977) extended this data base to include data through 1974 and fitted linear and exponential surplus production models to 1965-74 data. Data prior to 1955 were eliminated because the authors believed that the most significant changes in vessel efficiency took place before 1965. Later revisions in the number of vessels increased 1973 and 1974 effort estimates by 80-100 vessels. An MSY of 20,000-21,000 tons (whole weight) was estimated with f_{MSY} = 531-692 vessels. The model fitted the observed data quite well, even more so when observed 1961-64 catch figures were compared to their predicted values (Figure 29).

A later analysis (WECAFC, 1978) fitted a linear surplus production model to 1963-76 data, using the number of days at sea as the effort measurement, and a weighted average of annual CPUE estimates reported by individual countries. Total effort was estimated from total catch and sample CPUE estimates. MSY was estimated to be 18,580 tons and f_{MSY} was 78,100 days.

These results suggested that the resource is currently being exploited at or slightly below MSY. Problems which these analyses ignore and which therefore hinder the application of these results include: (1) the unknown harvest of juveniles in inshore waters, (2) changes in species composition over time, and (3) the possible existence of multiple stocks in the area, especially for white shrimp. Catch rate statistics from individual countries fishing in specific areas have indicated that the abundance of P. brasiliensis has declined on northern grounds over the past few years while P. subtilis have not decreased in abundance off Brazil and only slightly off the Guianas (WECAFC, 1979). Stocks of seabobs in shallow, nearshore waters are probably underutilized.

Table 41

Average annual landings, minimum and maximum annual landings and maximum sustainable yield estimates for unit shrimp fisheries in the Western Central Atlantic, in '000 tons whole weight

Unit Fishery	Years	Average annual catch	Range	MSY	Comments
Southeastern U.S.	1967-1976	12.3 1/	10.2-15.1	-	Inadequate effort data for MSY estimate
U.S. Gulf of Mexico	1963-1976	104.0 2/	89-118	122 3/	
Mexico:					
Tampico	1956-1975	8.2	4.7-11.3	-	Model did not fit data
Campeche	1956-1974	22.7	18.3-28.2	23-25	MSY not reliable
Contoy	1965-1975	1.2 4/	0.5-2.0	1.6	Poor fit to data
Honduras	-	-	3-4 5/	-	Data for assessment not available
Nicaragua	1967-1974	3.5	2.6-4.3	3.8	Good fit to data
Southeastern Cuba		-	4-5 5/	-	Data for assessment not available
Colombia	1972-1978	1.7	1.5-1.8	-	MSY=1.0 for southwest coast only
Venezuela:					
Gulf of Venezuela	1962-1976	3.7	2.1-6.8	3.0	MSY for brown shrimp only
N.E. Venezuela	1970-1976	1.0	0.4-1.2	0.5	MSY for Isla Margarita only
Atlantic coast	1973-1975	0.5	0.3-0.9	-	Insufficient data for estimating MSY
Guianas-Brazil	1963-1976	16.2	7.9-20.4	18.6	Good fit to data
Others 6/		5.0 5/			

1/ Includes 700 tons estimated recreational catch

2/ Includes 21,000 tons recreational and bait fisheries, estimated discards and non-penaeid species

3/ All species except seabob; includes recreational and bait fisheries plus discards

4/ Landings for U.S. fleet only

5/ Recent landings (early 1970s) according to Wise, 1976

6/ Jamaica, Dominican Republic, Guatemala, Costa Rica, Belize

Table 42

Reported 1963-1979 commercial catch and effort data* for brown, white and pink shrimp in the U.S. Gulf of Mexico - Weight is in whole weight

YEAR	BROWN SHRIMP			WHITE SHRIMP			PINK SHRIMP			TOTAL	
	Catch ('000 tons)	Effort ('000 days)	Unit effort ('000)	Catch ('000 tons)	Effort ('000 days)	Unit effort ('000)	Catch ('000 tons)	Effort ('000 days)	Unit effort ('000)	Catch ('000 tons)	Effort ('000 days)
1963	37.1	82.0	51.3	33.1	80.0	55.7	9.2	21.9	15.3	79.4	159.6
1964	26.9	74.1	48.0	31.0	95.3	63.3	10.5	25.0	18.5	68.4	194.4
1965	42.2	102.4	61.6	23.6	74.5	51.2	10.8	23.3	17.4	76.6	200.2
1966	42.7	111.9	73.6	21.2	72.1	43.6	10.3	23.1	17.5	74.2	207.1
1967	67.7	116.6	84.2	17.2	61.6	40.9	7.5	21.7	16.7	92.4	199.9
1968	52.6	117.8	84.9	21.5	77.4	52.0	8.4	22.4	17.5	82.5	217.6
1969	45.5	114.6	90.6	31.6	115.1	78.4	8.2	21.5	17.8	85.3	251.2
1970	55.7	117.4	86.7	32.5	91.3	72.6	9.4	20.2	16.8	97.6	228.9
1971	60.0	126.2	102.6	29.8	88.7	68.2	7.6	17.8	15.1	97.4	232.7
1972	60.2	144.0	113.6	26.8	91.8	76.3	8.1	21.5	18.7	95.1	257.3
1973	39.1	115.3	90.0	24.1	115.6	86.5	10.7	25.4	22.4	73.9	256.3
1974	41.3	103.8	74.9	22.2	96.1	67.5	11.2	27.1	23.9	74.7	227.0
1975	37.4	86.6	67.8	19.6	121.8	92.3	10.8	31.3	28.6	67.8	239.7
1976	57.6	181.9	130.3	25.9	111.4	87.7	9.6	29.4	26.2	93.1	322.7
1977	72.5	-	-	34.0	-	-	11.4	-	-	117.9	-
1978	65.4	-	-	34.1	-	-	11.5	-	-	111.0	-
1979	53.7	-	-	26.4	-	-	10.3	-	-	90.4	-
Mean	50.4 ±6.5			26.7 ±2.8			9.7 ±0.7			86.9 ±7.4	

Sources: 1963-1976 data from Griffin (1978) as reported by Gulf of Mexico Fishery Management Council (1980), 1977 data from Caillouet and Koi (1980), and 1978-1979 data courtesy National Marine Fisheries Service, Southeast Fisheries Center, Miami.

* Nominal 1963-1976 effort (days fishing) was converted to real effort (unit effort) on basis of the fishing power of different vessel types relative to a standard vessel; unit effort was used for yield analyses. Catch data were originally reported as million lbs tail weight and were converted to thousand tons using conversion factors of 0.74, 0.7 and 0.74 for brown, white and pink shrimp, respectively.

Table 43

Reported 1963-1976 and 1978-1979 commercial catch and effort* data for royal red, seabob and rock shrimp in the U.S. Gulf of Mexico - Catch data on a whole weight basis

Year	ROYAL RED SHRIMP		SEABOB SHRIMP		ROCK SHRIMP	
	Catch (tons)	Effort (days fished)	Catch (tons)	Effort (days fished)	Catch (tons)	Effort (days fished)
1963	4	8	800	709	-	-
1964	4	6	230	778	-	-
1965	14	27	500	790	-	-
1966	20	36	340	737	-	-
1967	31	88	150	575	-	-
1968	61	89	490	2420	-	-
1969	225	506	370	817	-	-
1970	34	66	1500	1905	-	-
1971	53	91	230	344	-	-
1972	30	35	1010	1635	153	167
1973	192	410	2090	3548	137	299
1974	188	504	3070	4350	47	58
1975	93	230	3230	4580	519	463
1976	136	382	520	1641	677	982
1978	90	-	1837	-	811	-
1979	128	-	3055	-	3299	-

Sources: 1963-1976 data from Gulf of Mexico Fishery Management Council, 1978-1979 data from National Marine Fisheries Service, Southeast Fisheries Center, Miami.

* Days fished for seabob and rock shrimp (1963-1975) were calculated by assuming that the fishing effort for a given trip was proportioned according to the weight of the various species caught and landed. Interviewed 'days fished' estimates were converted to 'total days fished' estimates by using the ratio of interviewed days fished to interviewed trips on an annual basis for royal red, seabob and rock shrimp, 1963-1975. Estimates of 1976 days fished for each species were taken directly from NMFS estimates.

Table 44

Estimates of annual catches by recreational and bait fisheries, and discards by shrimp fleet in the U.S. Gulf of Mexico, in '000 tons whole weight, for principal shrimp species*

Species	Recreational	Bait	Discards	Total
Brown shrimp (*P. aztecus*)	5.9	1.2	3.7	10.8
White shrimp (*P. setiferus*)	5.7	0.6	1.4-2.8	7.7-9.1
Pink shrimp (*P. duorarum*)	-	0.8	0.2	1.0
TOTAL :	11.6	2.6	5.3-6.7	19.5-20.9

Source: Gulf of Mexico Fishery Management Council, 1980

* Original data were by state and for all species combined and were broken down according to the percent species composition in reported commercial landings for individual states

Table 45

Estimates of maximum sustainable yield obtained from Schaefer surplus production models fit to commercial 1963-76 catch and effort data for three principal shrimp species in the U.S. Gulf of Mexico

SPECIES	MSY commercial data only		MSY plus other catches*
	10^6 lbs tail	10^3 tons whole	10 tons whole
Brown shrimp	84.6	62.8	73.6
White shrimp	38.5	27.3	35.7
Pink shrimp	14.4	10.6	11.6
TOTAL :	137.5	100.7	120.9

Source: Gulf of Mexico Fishery Management Council, 1980

* Recreational fishery, commercial bait fishery and discards of under-sized shrimp (see Table 44)

Table 46

Weekly instantaneous rates of growth and mortality for three species of shrimp in the U.S. Gulf of Mexico

Species	Natural Mortality M	Fishing Mortality F	Total Mortality Z	Growth K	Source
Brown shrimp	.21	.06	.27	-	Klima, 1964
	-	-	.99, 1.24	.07	McCoy, 1968
White shrimp	.08	.06-.19	.14-.27	.09	Klima & Benigno, 1965
	.04-.12	.10-.13	.16-.22	-	Klima, 1974
	-	-	.46	.12	Klima, 1964
Pink shrimp	.27	.09	.36	-	Iverson, 1962
	.55	.96	.76, 1.51	.07	Kutkuhn, 1966
	.08-.12	.12-.18	.25	-	Lindner, 1966
	.02-.06	.16-.23	.22-.27	.04-.06	Berry, 1967
	.08-.11	.03-.07	.11, .18	-	Costello & Allen, 1968
	.01-.03	.02-.16	.07-.16	-	Berry, 1970

Note: A range of estimates are designated as .03-.07 and two separate estimates as .03, .07
Sources: Berry (1970) and Gulf of Mexico Fishery Management Council (1980)

* Not included in original published material

Table 47

Tampico shrimp fishery:
Total catch, catch per effort and total effort

Year	Total catch 1/ (tons)	U.S. catch/ effort (kg/hr)	Total effort 2/ ('000 hrs)
1956	8,081	20.7	387
1957	11,295	24.4	463
1958	10,139	13.5	751
1959	10,574	15.7	674
1960	4,676	13.3	352
1961	8,279	18.3	452
1962	6,552	15.5	423
1963	5,514	16.2	340
1964	5,740	16.6	346
1965	6,328	18.1	350
1966	8,702	18.2	478
1967	7,546	20.5	366
1968	9,921	19.0	522
1969	6,408	13.9	461
1970	9,328	19.4	484
1971	8,294	16.9	491
1972	9,827	20.2	486
1973	8,241	16.3	506
1974	10,216	15.2	671
1975	9,099	16.9	539

Source: Western Central Atlantic Fishery Commission, 1978

1/ Whole shrimp

2/ Figures obtained by dividing total catch by U.S. catch per effort

Table 48

Campeche shrimp fishery:
Total catch, catch per effort and total effort

Year	Total catch 1/ (tons)	U.S. catch/ effort (kg/hr)	Total effort 2/ ('000 hrs)	Mexican catch/ effort (kg/hr)	Total effort 3/ ('000 hrs)
1956	23,572	20.5	1,150	17.0	1,327
1957	23,032	18.2	1,265	12.6	1,828
1958	19,513	16.2	1,205	10.9	1,790
1959	20,646	16.8	1,229	10.7	1,930
1960	22,873	19.7	1,161	9.1	2,514
1961	21,750	17.5	1,243	12.0	1,812
1962	22,758	15.5	1,468	11.5	1,980
1963	23,400	15.9	1,472	13.0	1,800
1964	26,287	17.9	1,469	12.5	2,103
1965	24,217	16.8	1,441	13.6	1,781
1966	18,285	14.8	1,235	12.3	1,487
1967	19,420	17.4	1,116	13.1	1,482
1968	21,924	18.2	1,205	11.8	1,858
1969	20,291	16.8	1,208	11.7	1,734
1970	22,583	12.9	1,751	11.2	2,016
1971	23,071	16.4	1,407	10.4	2,295
1972	28,171	24.4	1,155	13.1	2,150
1973	25,205	20.4	1,236	12.0	2,100
1974	24,863	29.2	851	14.7	1,691
1975	-	44.4	-	8.3	-

Source: Western Central Atlantic Fishery Commission, 1978

1/ Whole shrimp

2/ Figures obtained by dividing total catch by U.S. catch/effort

3/ Figures obtained by dividing total catch by Mexican catch/effort

Table 49

Contoy shrimp fishery:
Total catch, U.S. catch per effort and total effort
for all species and catch per effort for spotted pink shrimp (*P. brasiliensis*)

Year	Total catch 1/ (tons)	U.S. catch/ effort (kg/hr)	Total effort 2/ ('000 hrs)	Catch of spotted pink shrimp (tons)	Catch/effort of spotted pink shrimp (kg/hr)
1965	792	36.0	22	792	36.0
1966	516	43.0	12	516	43.0
1967	1,358 3/	28.3	48	1,358	28.3
1968	824 3/	26.6	31	808	26.1
1969	915 3/	20.3	45	869	19.3
1970	1,251 3/	29.8	42	1,238	29.5
1971	1,161	22.4	52	1,149	22.2
1972	1,608	41.1	39	1,431	36.6
1973	1,237	30.9	40	915	22.9
1974	2,043	58.8	35	572	16.5
1975	1,857	23.8	78	1,207	15.5

Source: Western Central Atlantic Fishery Commission, 1978

1/ Whole shrimp
2/ Figures obtained by dividing total catch by U.S. catch/effort
3/ Not including Mexican landings

Table 50

Nicaragua fishery:
Total catch, catch-per-unit-effort and fishing effort
in total number of boat-days

Year	Total catch (tons) 1/	Effort ('000 days)	Catch per unit effort (t/day fishing)
1958	877	-	-
1959	415	-	-
1960	200	-	-
1961	500	-	-
1962	862	-	-
1963	808	-	-
1964	1,300	2.3	0.57
1965	2,046	4.8	0.43
1966	1,727	3.3	0.52
1967	2,627	3.4	0.77
1968	3,331	4.9	0.68
1969	4,051	6.2	0.65
1970	3,036	5.2	0.58
1971	3,532	7.2	0.49
1972	4,328	9.8	0.44
1973	3,848	11.7	0.33
1974	3,512	10.0	0.35
1975	3,660	7.2	0.50
1976	3,399	8.0	0.42

Source: Western Central Atlantic Fishery Commission, 1978

1/ Whole shrimp

Table 51

Total catch, effort and catch per unit effort
for the shrimp fishery on the northeast and southwest coasts
of Colombia, all species combined

Northeast Coast

Year	Total catch (t whole shrimp)	Effort (days at sea)	Catch/effort (kg/day at sea)
1972	623	3,463	180
1973	493	2,942	168
1974	666	3,875	171
1975	655	4,323	152
1976	1,038	4,249	157
1977	816	5,117	159
1978	518	4,089	127
1979 1/	(500)	(2,677)	(187)

Southwest Coast

Year	Total catch (t whole shrimp)	Effort (days at sea)	Catch/effort (kg/day at sea)
1972	1,110	7,260	153
1973	1,043	5,569	187
1974	1,003	7,738	130
1975	993	7,713	129
1976	854	6,592	130
1977	930	7,940	117
1978	974	9,291	105
1979 1/	(667)	(5,842)	(114)

Source: Western Central Atlantic Fishery Commission, 1979.

1/ 1979 data for January-September only

Table 52

Gulf of Venezuela:
White shrimp total landings, catch-per-unit-effort (kg/day at sea) of the Maracaibo fleet, and estimated total effort in Maracaibo fleet units; brown shrimp total landings, catch per unit effort (kg/day at sea) of the Punto Fijo fleet and estimated total effort in Punto Fijo fleet units

White Shrimp

Year 1/	Total landings (tons)	Catch-per unit-effort (kg/day at sea of Maracaibo fleet)	Estimated total effort 2/
1962	885	292	3,030
1963	1,202	360	3,338
1964	1,036	361	2,869
1965	2,245	424	5,291
1966	1,342	130	10,315
1967	870	163	5,337
1968	1,730	176	9,826
1969	1,909	187	10,208
1970	4,153	250	16,612
1971	2,479	169	14,669
1972	1,857	130	14,284
1973	425	81	5,259
1974	701	100	7,010
1975	248	109	2,275
1976	267	112	2,384

Brown Shrimp

Year 1/	Total landings (tons)	Catch per unit effort (kg/day at sea of Punto Fijo fleet)	Estimated total effort 2/
1962	1,205	170	7,088
1963	1,314	126	10,428
1964	1,149	118	9,737
1965	2,315	238	9,711
1966	1,506	87	17,410
1967	4,068	196	20,755
1968	1,714	79	21,696
1969	1,788	76	23,526
1970	2,680	113	23,716
1971	4,219	149	28,315
1972	3,273	102	32,088
1973	2,070	74	27,973
1974	2,811	87	32,310
1975	1,863	86	21,663
1976	2,566	79	32,481

Source: Western Central Atlantic Fishery Commission, 1978

1/ Data until 1970 taken from Cadima *et al.* (1972)

2/ Number of days at sea, calculated by dividing total landings by catch/effort

Table 53

Unare platform (Venezuela) shrimp fishery:
Total catch, total effort and catch per unit effort

Year	Catch (tons)	Effort (days at sea)	Catch per unit effort (kg/day at sea)
1969	65	997	66
1970	242	1,410	172
1971	701	3,055	229
1972	710	4,577	155
1973	665	4,354	153
1974	711	4,617	192
1975	542	4,218	141
1976	429	4,662	123

Source: Western Central Atlantic Fishery Commission, 1978

Table 54

Shrimp fishery east of Isla de Margarita, Venezuela:
Total catch, total effort and catch per unit effort

Year	Catch (tons)	Effort (days at sea)	Catch per unit effort (kg/day at sea)
1970	143	1,116	128
1971	399	2,733	146
1972	321	3,955	81
1973	489	5,811	84
1974	531	7,566	70
1975	466	9,105	51
1976	529	8,803	60

Source: Western Central Atlantic Fishery Commission, 1978

Table 55

Shrimp fishery in the Gulf of Paria:
Total catch, total effort and catch per unit effort

Year	Landings, whole shrimp (tons)	Effort (days at sea)	Catch-per unit-effort (kg/day at sea)
1969	75	750	100
1970	87	908	96
1971	36	490	74
1972	28	337	83
1973	110	1,112	99
1974	146	1,205	122
1975	190	947	200

Source: Western Central Atlantic Fishery Commission, 1978

Table 56

Shrimp fishery south of Trinidad:
Total catch, total effort and catch per unit effort

Year	Landings, whole shrimp (tons)	Effort (days at sea)	Catch per unit effort (kg/day at sea)
1973	191	4,656	41
1974	217	1,130	192
1975	683	3,350	203

Source: Western Central Atlantic Fishery Commission, 1978

Table 57

Total catch, total effort and catch-per-unit-effort
for the Guianas/Brazil shrimp fishery for the years 1960-1978

Year	Catch 1/ (tons whole weight)	Effort 2/ (No.of vessels)	Effort 3/ ('000 days at sea)	Catch/ 4/ effort (kg/day)	Catch/ effort (t/vessel)
1960	2,785	-	-	-	-
1961	3,095	100	-	-	30.9
1962	4,371	96	-	-	45.5
1963	7,430	147	27.6	285	50.5
1964	9,262	187	23.5	417	49.5
1965	11,230	203	34.3	351	55.3
1966	15,475	281	53.1	309	55.1
1967	17,222	342	59.3	308	50.4
1968	19,259	362	68.7	287	53.2
1969	19,136	403	82.8	245	47.5
1970	19,081	421	90.0	225	45.3
1971	15,550	346	69.3	237	44.8
1972	16,126	370	72.8	230	43.6
1973	19,606	523	84.7	257	37.5
1974	17,687	561	99.2	180	31.5
1975	15,567	591	94.2	155	26.3
1976	16,753	586	88.0	170	28.6
1977	19,361	645	-	-	30.0
1978	15,188	501	-	-	30.3

1/ Reported by Western Central Atlantic Fishery Commission (1979); all figures were slightly lower than those reported by Naidu & Boerema (1972), and Jones and Dragovich (1977)

2/ Reported by WECAF Commission (1979); 1973 and 1974 figures were higher than those reported by Jones and Dragovich (1977)

3/ Reported by WECAF Commission (1978)

4/ Weighted average of catch rates for individual national fleets, using reported landings per fleet as a weighting factor, as reported by WECAF Commission (1978)

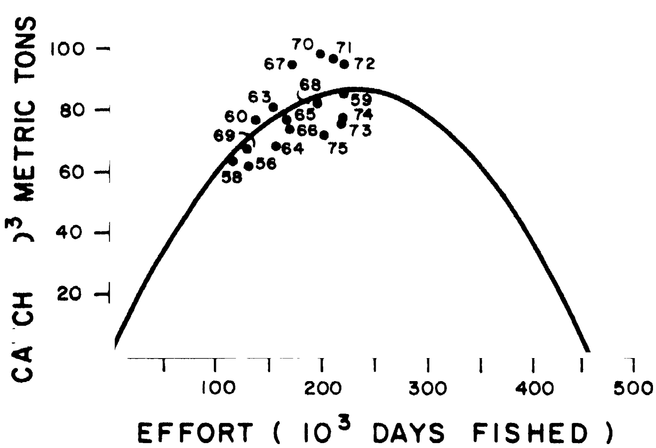


Figure 17 Annual estimated catch of all penaeid species and effort for the U.S. Gulf of Mexico shrimp fishery during the period 1956-1975, excluding three hurricane years, and the predicted yield curve. Catch is expressed in whole weight (Source: Klima and Parrack, 1978)

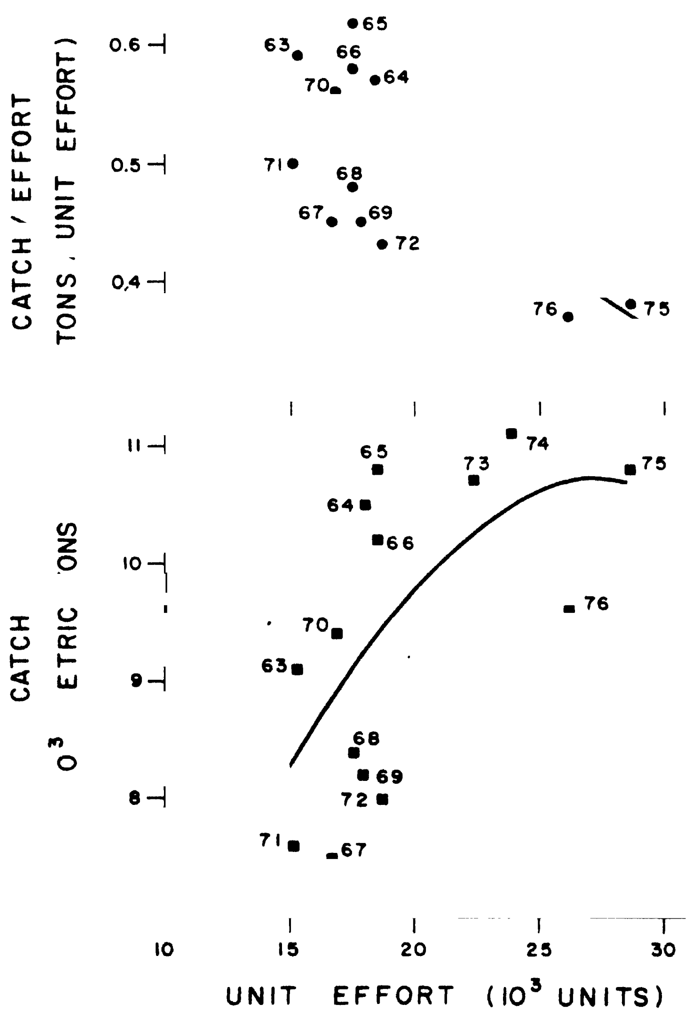
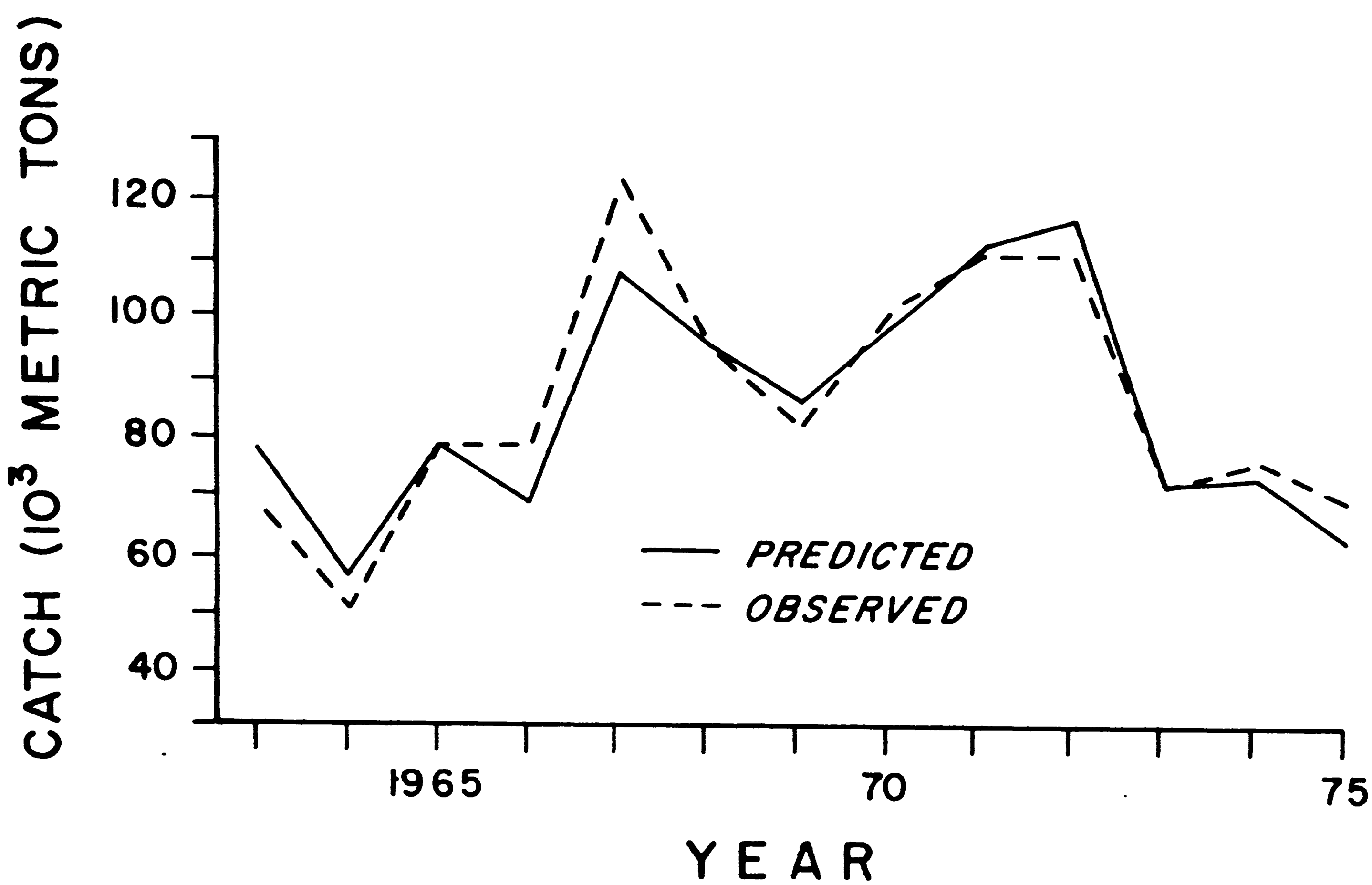


Figure 18 Linear regression of 1963-1976 CPUE versus standardized effort for pink shrimp (Penaeus duorarum) harvested by the U.S. trawl fishery in the U.S. Gulf of Mexico and the predicted yield curve. Catch is expressed in whole weight (Source: Gulf of Mexico FMC, 1980)



<u>Figure 19</u> Actual and predicted annual 1963-1975 catch in whole weight of brown shrimp (<u>Penaeus aztecus</u> by the U.S. shrimp fishery in the U.S. Gulf of Mexico. Catch was predicted from a multiple regression equation which incorporated environmental variables (Source: Gulf of Mexico FMC, 1980)

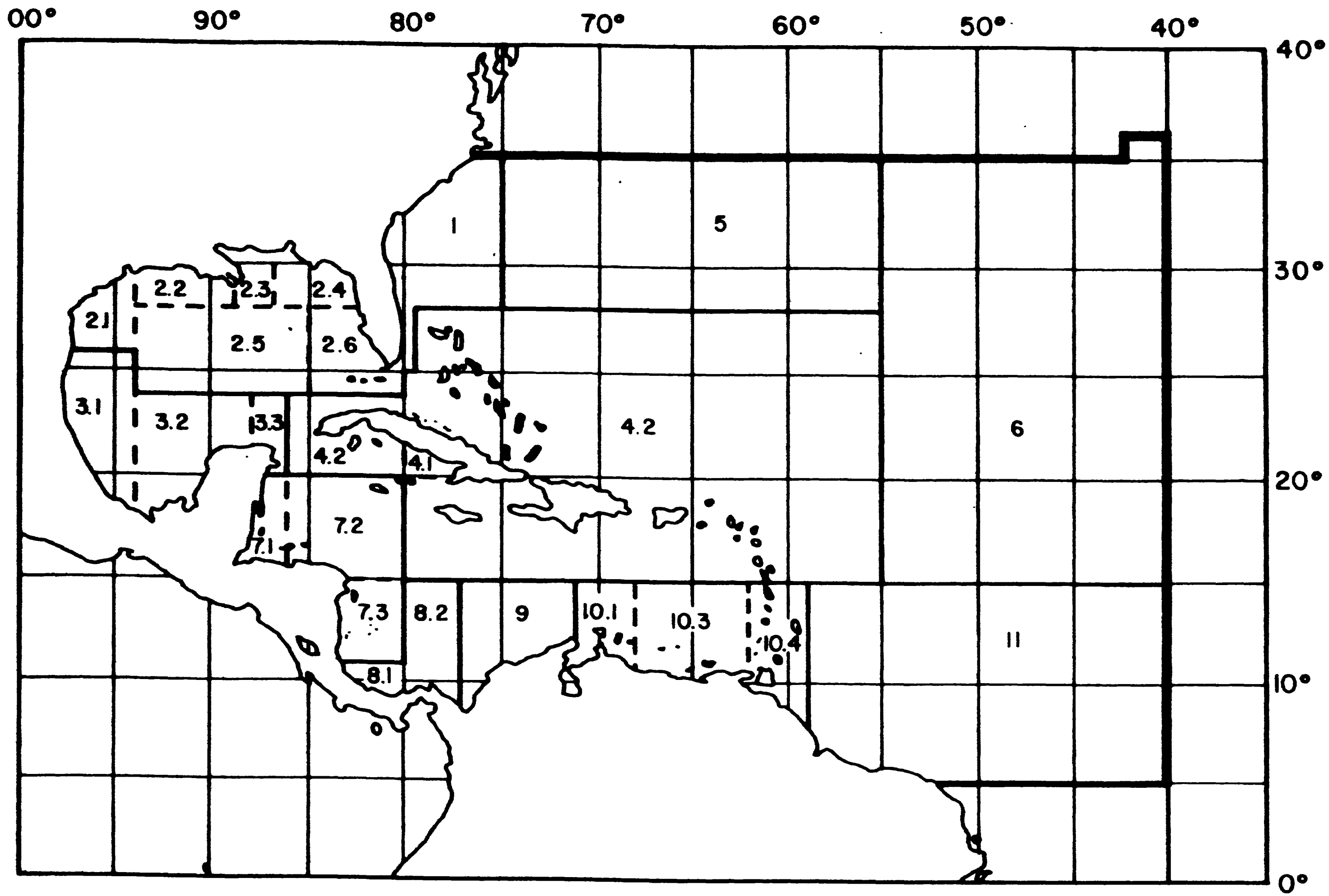


Figure 20 The original Western Central Atlantic region (FAO statistical area 31) showing statistical sub-areas

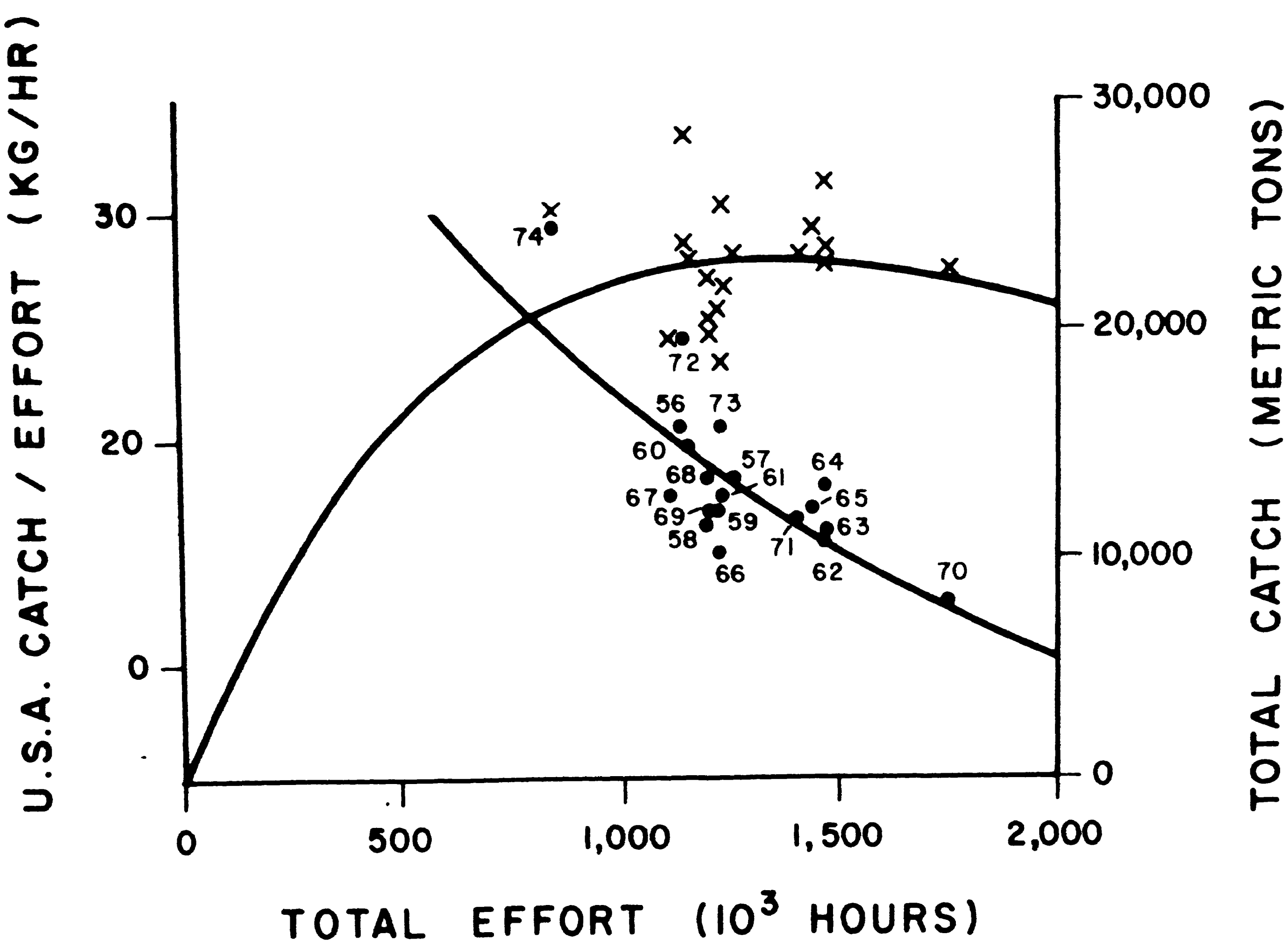


Figure 21 Exponential regression of estimated 1956-1974 U.S. CPUE versus effort data for all species of penaeid shrimp harvested by the U.S. fleet operating on the Campeche (Mexico) grounds and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1978)

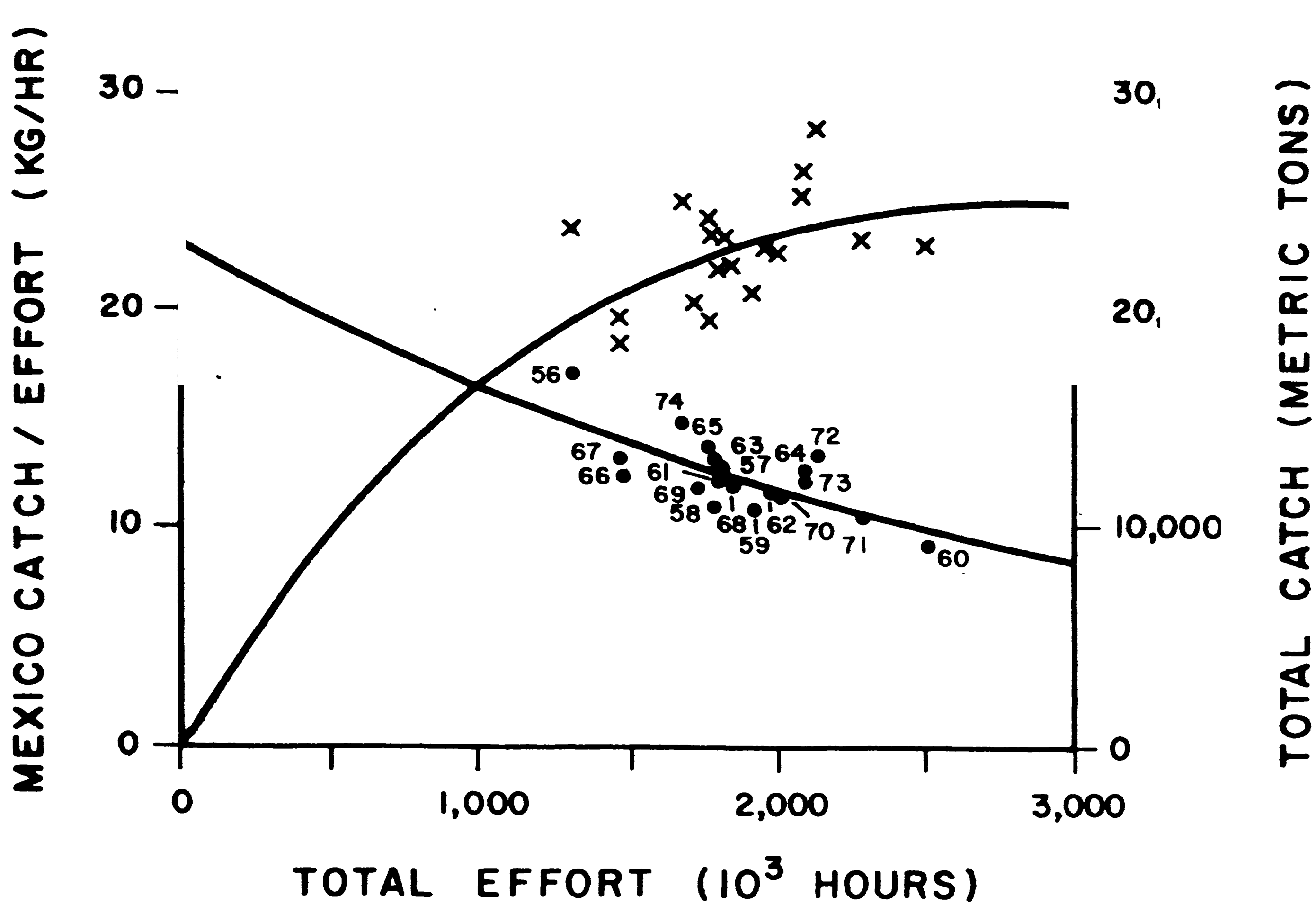


Figure 22 Exponential regression of estimated 1956-1974 Mexican CPUE versus effort for all species of penaeid shrimp harvested by the Mexican fleet operating on the Campeche (Mexico) grounds and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1978)

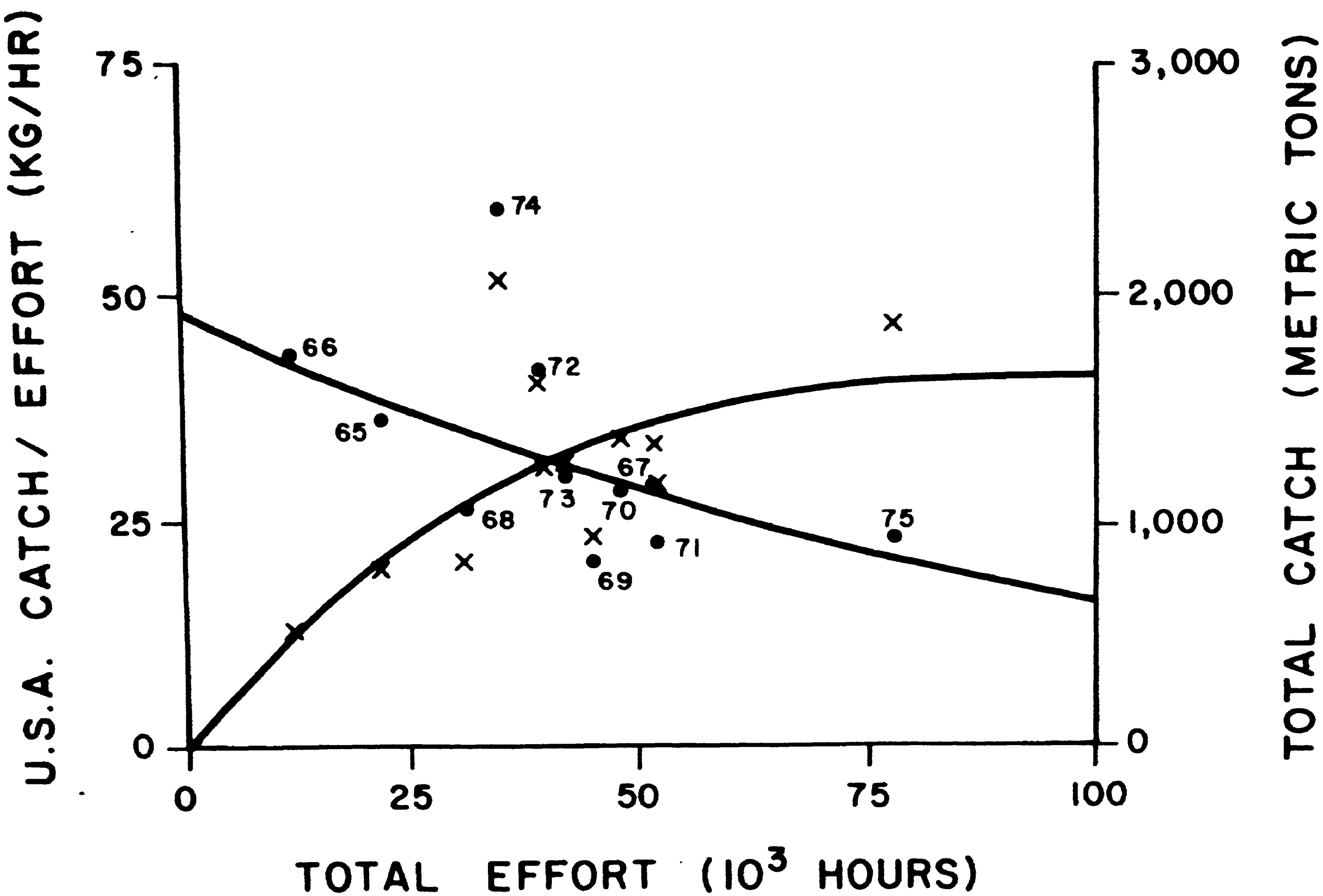


Figure 23 Exponential regression of estimated 1965-1975 U.S. CPUE versus effort for two species of penaeid shrimp and rock shrimp (*Sicyonia brevirostris*) harvested by the U.S. fleet operating on the Contoy (Mexico) grounds and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1978)

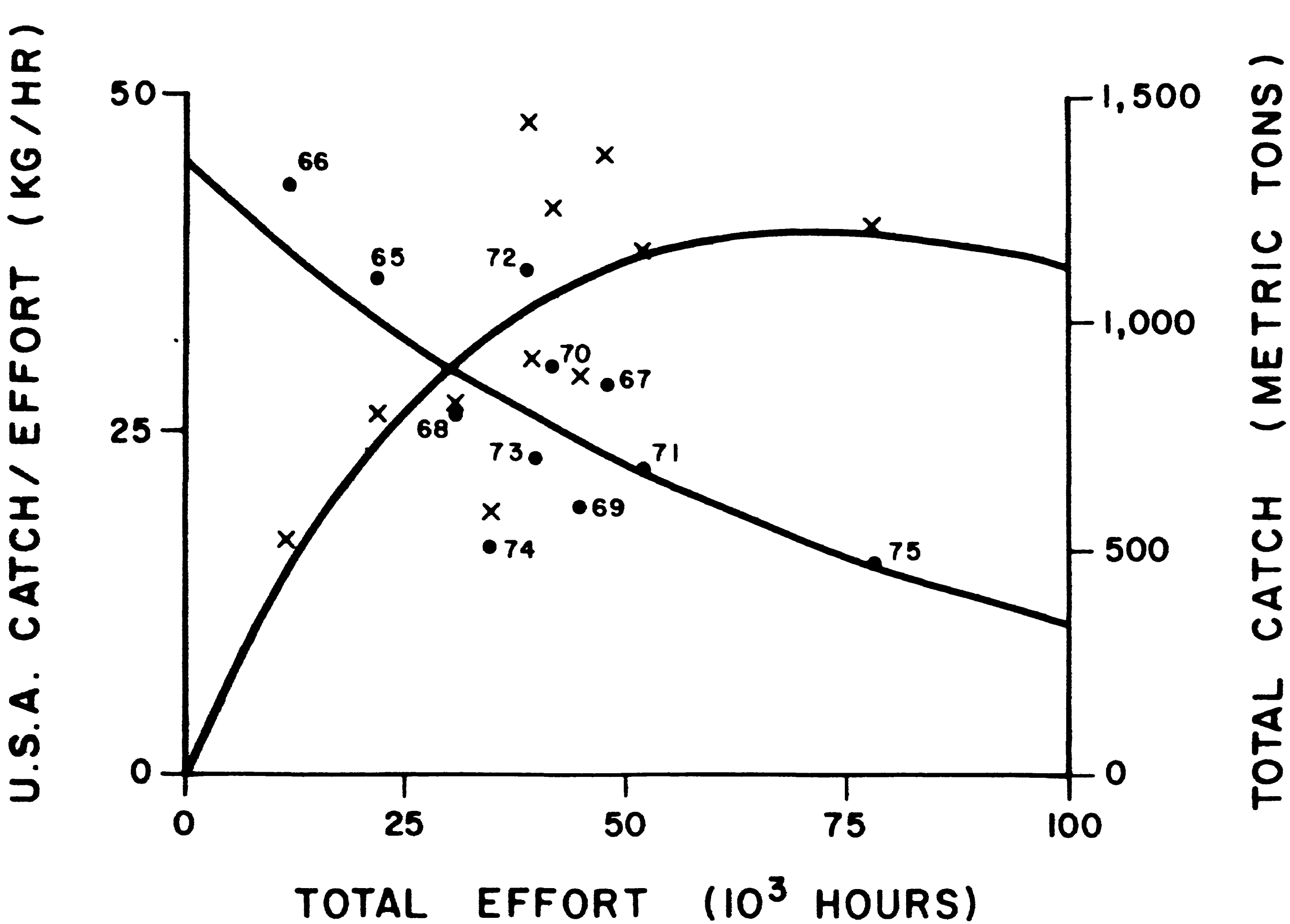


Figure 24 Exponential regression of estimated 1965-1975 CPUE versus effort for spotted pink shrimp (Penaeus brasiliensis) harvested by the U.S. fleet operating on the Contoy (Mexico) grounds and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1978)

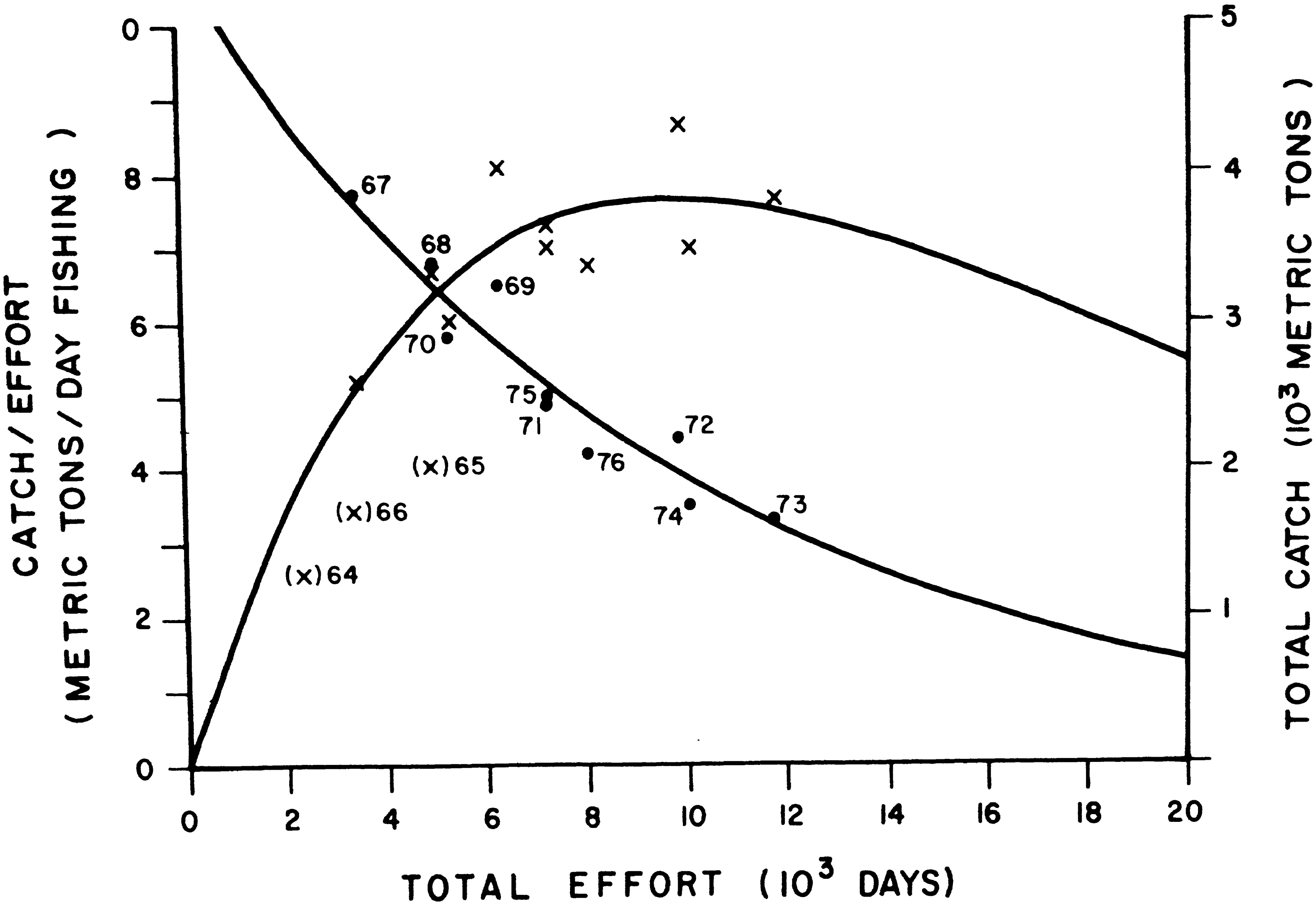
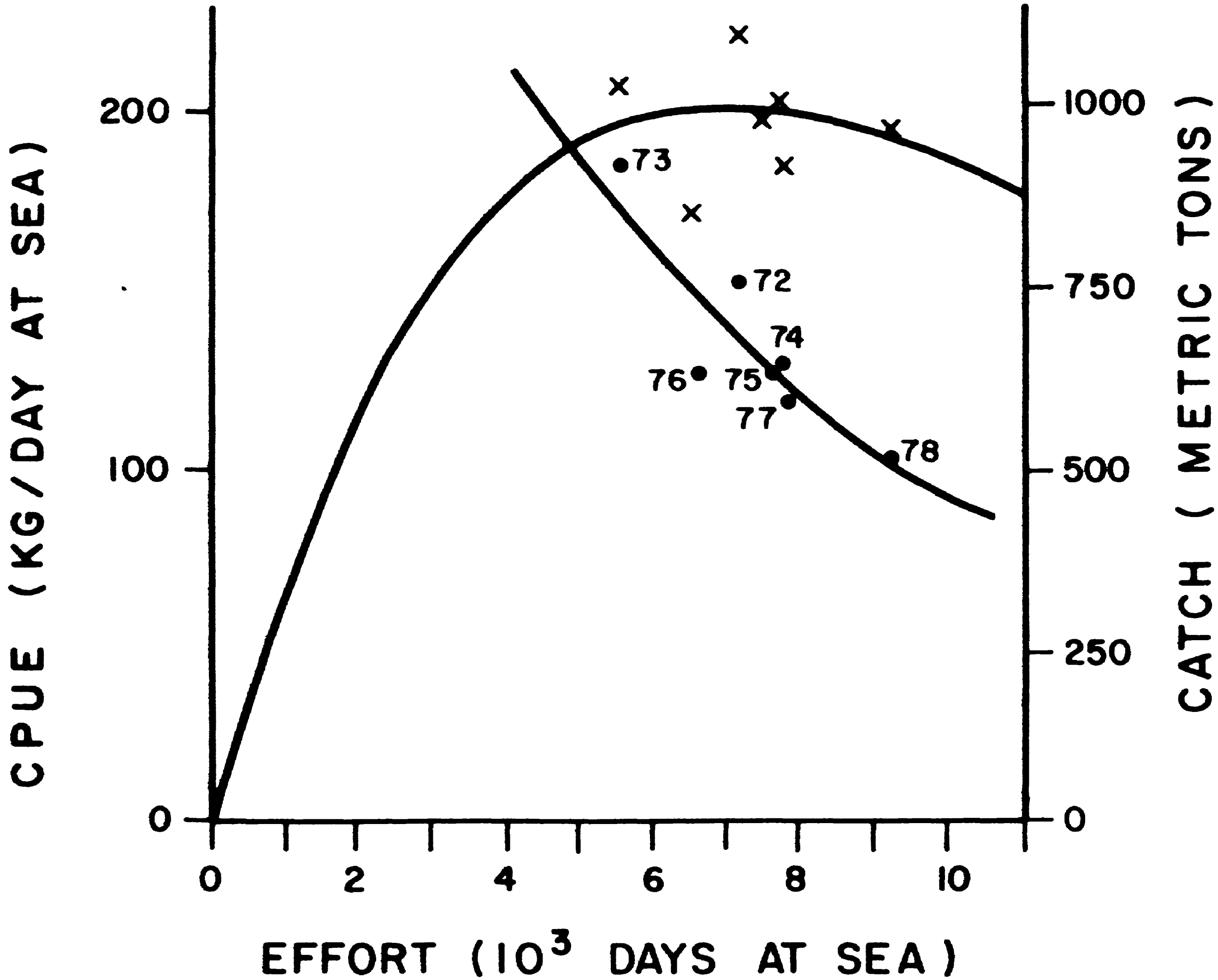


Figure 25 Exponential regression of 1967-1976 CPUE versus effort for all species of penaeid shrimp in the Caribbean Nicaraguan fishery and the predicted yield curve. 1964, 1965 and 1966 catch data were plotted, but were excluded from the analysis. Catch is in whole weight (Source: WECAF, 1978)



gure 26 Exponential regression of estimated 1972-1978 CPUE versus effort for all species of penaeid shrimp harvested on the southwest Caribbean coast of Colombia and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1979a)

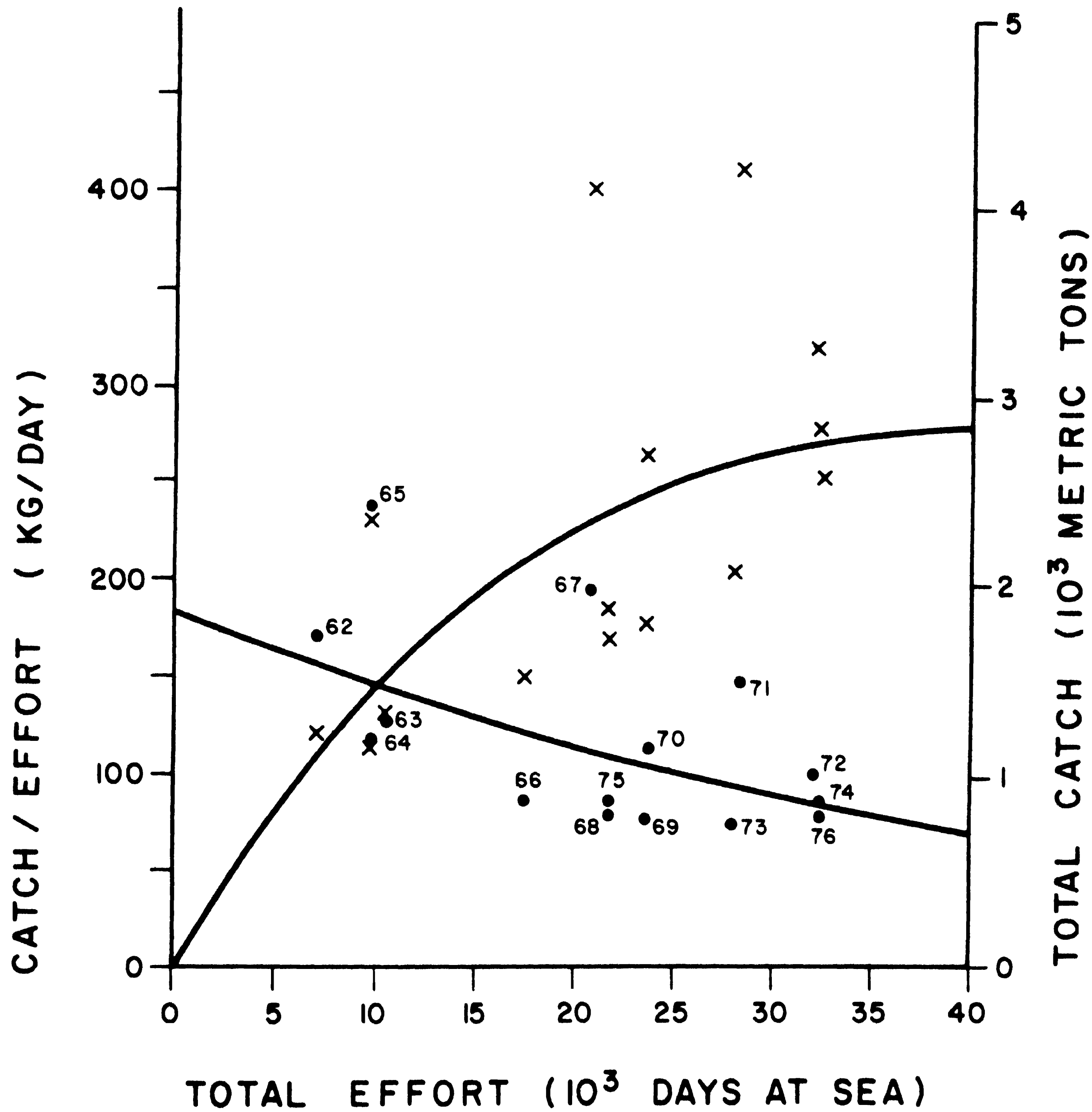


Figure 27 Exponential regression of estimated 1962-1976 CPUE versus effort for three species of brown shrimp (Penaeus subtilis, P. brasiliensis and P. notialis) harvested in the Gulf of Venezuela and the predicted yield curve (Source: WECAF, 1978)

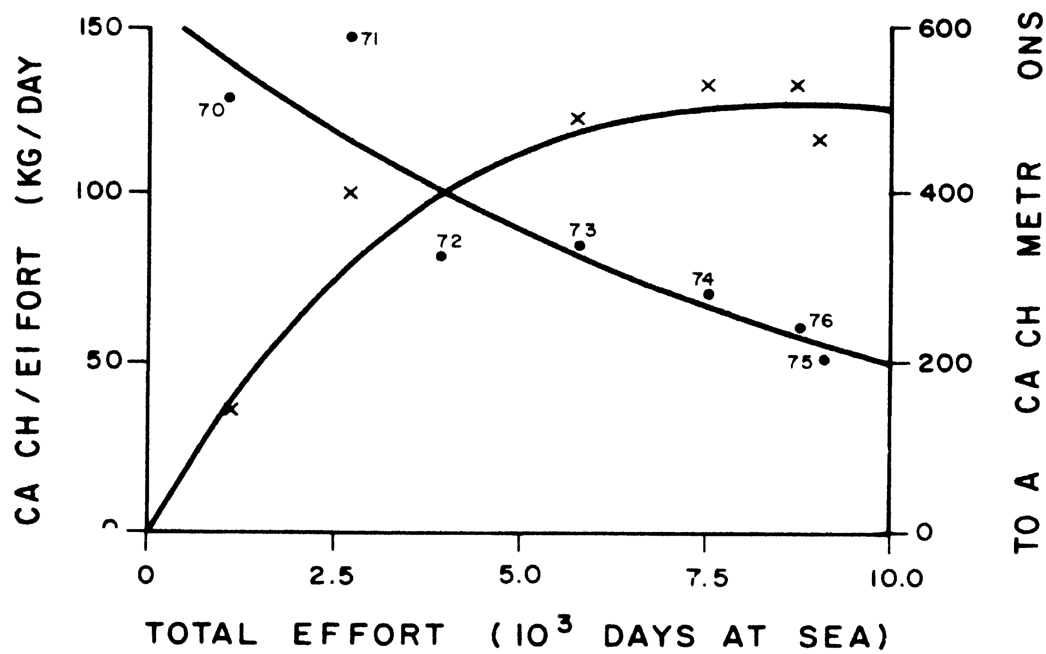


Figure 28 Exponential regression of estimated 1970-1976 CPUE versus effort for all species of penaeid shrimp harvested in the vicinity of Isla Margarita in eastern Venezuela and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1978)

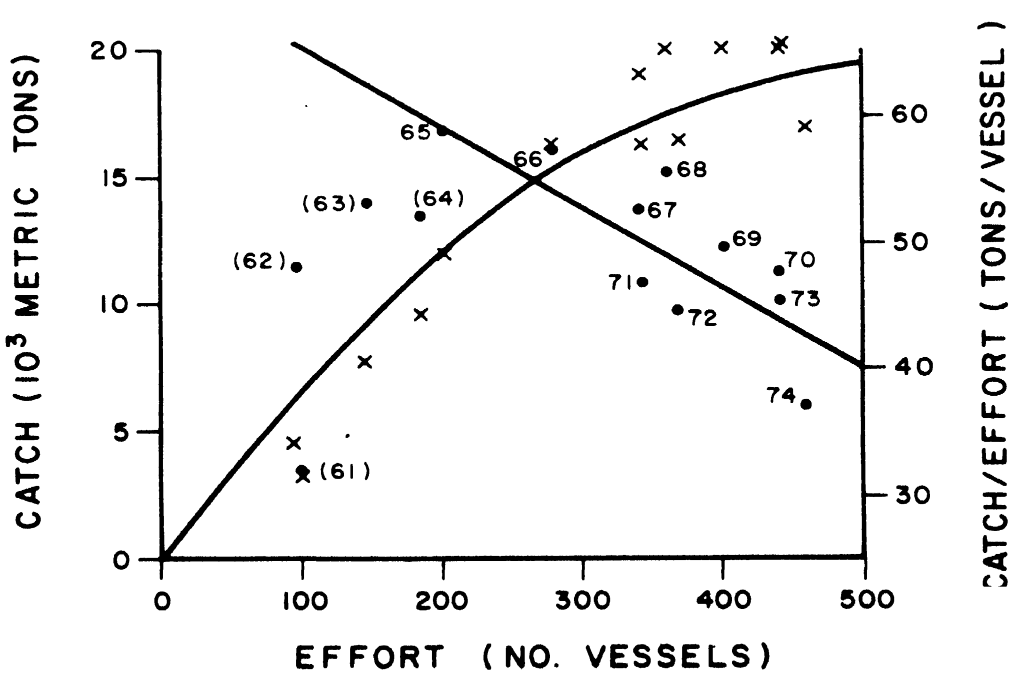


Figure 29 Linear regression of estimated 1965-1974 CPUE versus effort for all species of penaeid shrimp harvested off the Guianas and northern Brazil and the predicted curve. 1961-1964 CPUE and catch data were plotted, but were excluded from the analysis. Catch is in whole weight (Source: Jones and Dragovich, 1977)

CHAPTER 8: SPINY LOBSTER

The Western Central Atlantic supplied 16% of the total world lobster production in 1978 with reported landings of 31,000 tons (Table 58). Landings have increased by 5,000 tons since the early 1970s and by 11,000 tons since the late 1960s. Total landings estimated by Wise (1976) during 1965-1973 were slightly higher than those reported by FAO.

Major lobster producing countries in the region are Cuba, Brazil, Nicaragua, the Bahamas and the U.S. These five countries accounted for 88% of the total reported landings during 1977 (FAO, 1979). The most notable increases during the last ten years have taken place in Brazil and Nicaragua (Table 59). Estimated Brazilian catches have increased by 3,000-4,000 tons during the last ten years while landings from Nicaragua's Atlantic coast increased from 700 tons in 1974 to 3,200 tons in 1978. U.S. landings increased from an estimated average of 2,100 tons a year in 1960-1969 to 4,600 tons in 1970-1973 as the FLorida-based fleet moved into the Bahamas. In 1975, the Bahamas excluded foreign fishing and U.S. landings returned to previous levels while Bahamian landings increased.

The predominant species harvested is Panulirus argus. Small quantities of Panulirus laevicauda and Panulirus guttatus are also harvested as well as insignificant quantities of "slipper lobster" of the family Scyllaridae. Traps are the principal fishing gear used throughout the region, although other gears are common in some areas. The spiny lobster fishery is conducted at small-scale and large-scale levels. Closed fishing seasons are common during February/August as are size limits ranging from 20-30 cm total length or 8.5-10 cm carapace length. The taking of egg-bearing females is prohibited in most areas.

Assessments

Estimates of potential catch made by Wise (1976) for individual countries, based largely on an intuitive interpretation of current landings and the extent of under-exploited fishing grounds which still exist, totalled 42,200 tons for the entire WECAFC region. This estimate was probably on the conservative side, however, since the current dramatic increases reported from Nicaragua demonstrate the degree to which potentials based on past performance may be under-estimated.

A complicating factor which hinders the assessment of lobster stocks is the possibility that planktonic larvae are transported long distances by currents, thus reducing the chance that fishing in a given location will affect recruitment and catches only in that location in subsequent years (Menzies & Kerrigan, 1979). In practice any impact of heavy fishing in one location may be spread over recruitment on many areas, and be very difficult to evaluate. Very little is known about possible lobster stock delineations in the region.

Brazil

Catch and effort data collected from the Brazilian lobster fishery since 1965 have been analysed by various authors (Coelho et al., 1974; Costa et al., 1974; Paiva et al, 1971; Santos et al., 1973). Their results were summarized by Wise (1976) who concluded that the resource will sustain an annual yield of 8,500 tons with 22 million trap-days of effort. This conclusion was confirmed (Programa de PDP do Brasil, 1977) by more recent MSY estimates of 8,800 tons and f_{MSY} = 18.8 million trap-days based on data through 1976 (Table 60). Separate analyses by geographical area (WECAFC, 1979a) indicated that the resource was larger north of the equater (MSY = 7,300 tons) than south of the equator (MSY = 2,000 tons), but was also more heavily exploited. A linear surplus production model provided a better fit to the observed data collected north of the equator (Figures 30 and 31). Effort north of the equator in 1977 accounted for 75% of total effort and exceeded f_{MSY} by 60% (Table 61). Present yield is equal to or slightly less than MSY, but effort is excessive. Total Brazilian catch-per-unit-effort has declined from more than one kg/trap-day in 1964 to 0.3 kg/trap-day since 1973. However, the increased number of traps in use in recent years and the expansion of the fleet into more offshore waters has apparently increased trap soak times beyond one day, thus reducing the validity of catch/trap-day as a reliable index of abundance (Frederick and Weidner, 1978) since traps left for longer periods of time do not perform as efficiently on a per-day basis. Panulirus laevicauda reportedly accounted for a larger percentage of total landings north of the equator in 1976 and 1977 than south of the equator (Programa de PDP do Brasil, 1978a).

Jamaica

Munro (1974a) assessed spiny lobster resources on the Jamaican shelf and on Pedro Bank with yield/recruit models. Mortality rates were obtained from length frequency data collected on the heavily exploited south Jamaican reefs and from Pedro Bank. Lobster on the Bank are exploited in the area of the Cays at the extreme eastern end of the Bank, but the resource on the remainder of the Bank was considered to be unexploited. The natural mortality rate from Pedro Bank (M=1.03) was reduced for the exploited populations on the Cays and the inshore Jamaican reefs by multiplying 1.03 times the relative biomass of predatory fish on the different fishing grounds (Table 62). Growth was estimated as K = 0.215 from tagging studies in Belize and Florida. Fishing mortality rates for the exploited stocks on the south Jamaican and Pedro Bank reefs were estimated from values of fishing effort (number of canoes per unit area) and the catchability coefficient (0.206) and equalled 0.27 and 0.10 respectively. Fishing mortality on the heavily exploited Port Royal reefs was estimated as Z-M = 1.52-0.14 = 1.38.

For the south Jamaican shelf, the model predicted that MSY would be achieved at twice the observed size-at-first-capture (l_c = 60 mm carapace length) at a constant exploitation rate. For other more heavily exploited areas of the coast, lobster were captured at even smaller sizes and were consequently more extensively overfished. On the other hand, the stocks exploited by the Pedro Cays fishery were substantially underutilized. The model predicted that yield on the south coast of Jamaica could be increased by about 15% if l_c were increased to the same value which prevailed in the Cays, i.e. about 100 mm carapace length.

United States

The U.S. lobster fishery was established in south Florida by 1920. The trap fishery expanded rapidly in the late 1940s. After 1965, over 50% of the Florida landings came from foreign waters, mostly from the Bahamas. After 1975, the Bahamas were closed to U.S. fishermen. Since effort estimates (number of traps) for the entire Florida fishery fail to distinguish between effort expended on different grounds, surplus production models have been fitted to 1952-1975 catch and effort data (Table 63) for Munroe County, Florida, an area on the west coast which has traditionally supported a domestic fishery (Gulf of Mexico and South Atlantic FMCS, 1979a). The best fit to the data was obtained from an exponential (Fox) model. MSY estimates (Table 64) were increased by estimates of the recreational catch (10% of the average 1964-1977 commercial catch), domestic landings by the east coast fishery (10% of the MSY), and the unreported catch of undersized lobsters which was estimated to be 10% of the 1975 catch, but was not significant in previous years. Effort at MSY was increased by 10% to account for the east coast fishery.

Several MSY estimates were obtained using slightly different data sets. Dramatic increases in effort were observed after 1969 (Table 63). Effort in 1975 was so extreme (almost twice the 1974 effort and over four times the 1969 effort) that the estimate obtained from the 1952-1974 data set seemed more plausible, i.e. MSY ≤3,000 tons. Catch and effort data compiled since 1970 were critical since the data compiled in the 1950s and 1960s were clustered within a narrow effort range (Figures 32 and 33). Predicted MSY was exceeded for the first time on the west coast in 1970 and 1974 and f_{MSY} in 1974-1976.

A-yield-per-recruit model has also been applied to the Florida west coast lobster fishery. Total mortality (Z) estimates were obtained from growth rate estimates of $K_1 = 0.16$ and $K_2 = 0.215$ (for three and four annual molts) and length parameters derived from length-frequency data reported on four different occasions from Florida waters (Table 65) according to the Beverton-Holt (1956) equation:

$$Z = K \frac{(L_\infty - \bar{l})}{(\bar{l} - l_c)} \qquad (5)$$

where,

L = the asymptotic maximum length
l_c = size-at-first-capture
$\bar{l}$ = mean size beyond l_c

Each Z estimate was associated with a different fishing effort and natural mortality was estimated to equal 0.83 from the regression of Z versus effort (Table 66). However, following Munro's (1974a) suggestions that the principal source of natural mortality of lobsters is predation and that the abundance of large predatory fish is reduced in exploited reef areas, a minimum value of M was calculated to equal 0.4 from an estimate of F obtained from the exploitation rate equation ($E = F/Z$) when Z was estimated from the most recent available size data (Warner et al., 1977) for male and female lobsters, the length-weight relationship reported by Munro (1974a) and two different growth rates (Table 65) and the exploitation rate was estimated from Allen's (1953) equation:

$$E = W_c / \bar{W}$$

where,

W_c = weight-at-first-capture
$\bar{W}$ = mean weight at capture

In this instance, $W_c = 305$ g, $\bar{W} = 410$ g, and $E = 0.74$. Unadjusted natural mortality rates for Panulirus argus estimated by four different authors varied from 0.40 to 1.03 (Table 66), but were generally greater than 0.80.

Yield-per-recruit curves were derived for three estimates of M (0.83, 0.40 and 0.60) and two estimates of K (0.16 and 0.25), and were all "flat-topped", indicating that very small increases in yield would be obtained from considerable increases in effort. The authors, using the average $M = 0.60$ and $K = 0.20$, and setting l_c equal to 75 mm (the current minimum legal size in Florida), concluded that the Florida fishery was currently taking 95% of the maximum yield given the current level of effort (500,000 traps), but that the same yield could be taken with half the effort.

The model was of little practical use for management purposes, but it did suggest that lobster populations can withstand considerable fishing effort, a conclusion that also seems apparent when one considers the negligible change in catch following recent dramatic increases in effort in Florida (Table 63). Maximum Y/R predictions were very sensitive to changes in parameter values and the usefulness of the model is limited as long as recruitment is a significant variable.

Puerto Rico and U.S. Virgin Islands

Assessments have been performed with very limited information for the lobster resources in Puerto Rico and the U.S. Virgin Islands (Caribbean FMC, 1978). Catch and effort data for two years (1951 and 1976) in Puerto Rico were used to estimate an MSY of 234 tons and f_{MSY} of 6,500 traps. A total MSY of about 400 tons was estimated for the entire area from a natural mortality rate of 0.5 and a virgin stock biomass estimate based on a calculation of the amount of potential habitable reef area and an average density per unit area. Lobster density (7-19 kg/ha) was based on observations made during Tektite dives in the Virgin Islands and was higher than density estimates from other locations in the Caribbean (Table 67). Current catches for Puerto Rico and the Virgin Islands are near the predicted MSY.

Venezuela

Cabo de Barany et al. (1972) fitted an exponential surplus production model to catch-per-unit-effort and effort data collected from a small lobster fishery in Los Roques Archipelago, Venezuela, for eight fishing seasons (1962/63-1969/70). Effort was averaged for a two-year period, assuming that lobsters remain in the exploitable size range for four years. The results (MSY = 145 tons, f_{MSY} = 6,000 traps) were obtained by extrapolating the predicted yield curve to a presumed maximum. This assessment has been updated with annual data through 1977 (Table 68). A linear model (Figure 34) produced a MSY estimate of 130 tons and a f_{MSY} estimate of 9,000 traps. The 1974 data were omitted from the analysis. The model indicated that the stock was overexploited between 1964 and 1973. The amount of effort expended since 1974 has diminished to well below f_{MSY}, producing much higher catch-per-unit-effort. No appreciable increase in yield over present levels can be expected.

Table 58

Reported and estimated annual landings of spiny lobsters in the Western Central Atlantic, 1960-1978

Reported Landings ('000 tons)

Years	Area 31 1/	Northern Brazil	Total
1965-69	15.3	4.6 2/	19.9
1970-73	18.2	8.0 2/	26.2
1970-77	18.9	7.9 2/	26.8
1978 3/	23.5	7.6 1/	31.1

1/ FAO Statistical Yearbooks
2/ Programa de Pesquisa e Desenvolvimento Pesqueiro do Brasil, 1978a
3/ Preliminary data

Estimated Landings ('000 tons)

Years	Area 31	Northern Brazil	Total
1965-69	16.3	4.5	20.8
1970-73	20.0	7.9	27.9

Source: Wise, 1976

Table 59

Average annual landings of spiny lobsters for major producing countries in the WECAFC region

Country	1960-69 1/	1970-73 1/	1974-78
Cuba	8,560	8,950	9,600 2/
Brazil	3,760	7,900	7,700 3/
U.S.A.	2,120	4,600	3,120 2/
Nicaragua	440	580	2,330 2/
Bahamas	1,360	1,280	2,070 2/

1/ From Wise (1976)
2/ FAO Statistical Yearbooks
3/ Programa de Pesquisa e Desenvolvimento Pesqueiro do Brasil, 1978a

Table 60

Catch, fishing effort and catch per unit effort data for the Brazilian spiny lobster fishery, 1965-1977

Year	Total Catch ('000 t)	Fishing Effort (million trap days)	Yield (kg per trap day)
1965	3.5	3.1	1.12
1966	3.2	4.0	.81
1967	3.1	4.5	.69
1968	5.5	8.3	.67
1969	7.8	13.9	.57
1970	8.3	14.5	.58
1971	7.1	14.7	.48
1972	8.5	22.4	.38
1973	7.9	27.3	.29
1974	9.2	25.6	.36
1975	6.6	24.1	.27
1976	7.0	26.4	.27
1977 1/	8.3	28.6	.29

Source: Programa de Pesquisa e Desenvolvimento Pesqueiro do Brasil, 1978a

1/ 1977 data were not included in the yield analysis

Table 61

Catch, fishing effort and catch-per-unit-effort for spiny lobster (Panulirus argus and Panulirus laevicauda) harvested north and south of the equator in northern and northeastern Brazil, 1965-1977.
Weights are whole weight and were calculated from tail weights

Year	NORTH OF THE EQUATOR			SOUTH OF THE EQUATOR		
	Catch (tons)	Effort (10^6 trap-days)	CPUE (kg/ trap-day)	Catch (tons)	Effort (10^6 trap-days)	CPUE (kg/ trap-day)
1965	2544	2.1	1.21	963	1.0	0.91
1966	2520	3.1	0.81	722	0.9	0.77
1967	2832	4.0	0.71	282	0.5	0.61
1968	4757	6.5	0.73	779	1.2	0.66
1969	6267	11.5	0.54	1557	2.4	0.66
1970	6180	10.8	0.57	2199	3.7	0.59
1971	5526	12.0	0.64	1648	2.7	0.61
1972	6541	16.4	0.40	1994	6.0	0.33
1973	6431	23.2	0.28	1466	4.1	0.36
1974	6875	16.9	0.41	2356	8.7	0.27
1975	5385	20.2	0.27	1294	3.9	0.33
1976	5490	20.4	0.27	1461	6.0	0.24
1977	6836	22.1	0.31	1465	6.7	0.22

Source: Programa de Pesquisa e Desenvolvimento Pesqueiro do Brasil, 1978a

Table 62

Relative biomass estimates of predatory fishes on inshore and offshore Jamaican reefs as determined from catch rates in hexagonal wire fish traps

Area	Catch Rate (kg/1000 trap-nights)	Relative Biomass
Unexploited Pedro Bank	718.3	1.00
Pedro Cays area	355.8	0.50
California Bank	188.9	0.26
South Jamaican shelf	161.0	0.22
Port Royal reefs	53.7	0.14

Source: Munro, 1974a

1/ Observed estimate (0.07) doubled since traps in this location were unbaited

Table 63

Catch, fishing effort and catch-per-unit-effort-data for the Munroe County, Florida, spiny lobster fishery, 1952-1976

Year	Catch (tons)	Effort (No.of traps)	CPUE (kg/trap)
1952	440	4,500	98.2
1953	405	6,500	61.8
1954	335	11,690	28.6
1955	560	12,700	42.9
1956	1065	16,775	63.1
1957	1560	21,720	71.0
1958	1075	23,221	46.1
1959	1215	33,612	35.9
1960	980	54,640	18.0
1961	970	38,990	24.9
1962	1120	58,250	19.4
1963	1275	60,050	21.2
1964	1300	73,553	18.0
1965	2020	89,700	22.6
1966	1690	74,550	22.6
1967	1260	91,800	13.8
1968	1805	98,500	18.4
1969	2145	96,955	22.1
1970	3160	150,050	21.2
1971	2205	147,037	14.8
1972	2257	174,490	12.9
1973	2440	171,590	14.3
1974	2950	227,250	12.9
1975	2295	428,250	5.5
1976 1/	1905	305,000	6.4

Source:
National Marine Fisheries Service, Fishery Statistics of the United States, modified and reported by the Gulf of Mexico and South Atlantic FMCs, 1979a

1/ Unpublished preliminary figures

Table 64

Adjusted and unadjusted maximum sustainable yield (MSY) estimates and corresponding amount of fishing effort (f_{MSY}) for the U.S. South Florida spiny lobster fishery

Years	MSY (tons)	Adjusted MSY 1/	f_{MSY} (No.of traps)	Adjusted f_{MSY} 2/
1952-75	2645	3360	176,000	194,000
1952-74	2440	2930		
1952-71	2070	2485		

Source: Gulf of Mexico and South Atlantic FMCs, 1979a

1/ Adjusted to include recreational catch, unreported commercial landings and landings from U.S. waters by Florida east coast fishery

2/ Adjusted to include effort in U.S. waters by Florida east coast fishery

Table 65

Length parameters obtained from data collected from Florida lobster populations, on four different occasions, and resulting total mortality estimates, estimated for two different growth rates

Parameter	Source			
	Davis (1977)	Dawson & Idyll (1951)	Robinson & Dimitriou (1963)	Warner et al. (1977)
L_∞ 1/	190	190	190	190
l_c 2/	65	75	75	65
$\bar{l}$ 2/	89	93	89	78
Z_1	.68	.86	1.15	1.38
Z_2	.90	1.13	1.51	1.81

1/ Z was estimated separately from different L_∞ estimates for males and females, since males grow to a slightly larger size (L_∞ = 200 mm), but Y/R analyses were only carried out for L_∞ = 190 mm

2/ Length parameters expressed in mm carapace length.

Table 66

Estimates of natural mortality rates
for Caribbean spiny lobster (*Panulirus argus*)

Source	Location	M	Method
Munro, 1974a	Pedro Bank	1.03	Catch curves for unexploited stock
Gulf of Mexico and S.Atlantic FMCs, 1979a	Florida	0.83	Regression of total mortality versus effort
Olsen and Koblick, 1975	U.S. Virgin Islands	0.41-0.65	Catch curve analysis
Santos & Ivo, 1973	Brazil	0.94	Regression of total mortality versus effort in two different years

Table 67

Estimates of adult spiny lobster (*Panulirus argus*) densities
for various locations in the Caribbean

Source	Location	Density (kg/km^2)	Method
Peacock, 1974	Barbuda	135-256 1/	Tagging study
Cabo de Barany *et al.*, 1972	Los Roques, Venezuela	162 2/	Catch rates
Vidaeus, 1970	Jamaican Shelf	159 2/	Catch rates
Olsen *et al.*, 1975	U.S. Virgin Islands	700-1900 1/	Observation

1/ Standing stock estimates

2/ Production figures

Table 68

Catch, fishing effort and catch-per-unit-effort for the spiny lobster fishery in Los Roques Archipelago, Venezuela; 1962-1977

Year	Catch (tons)	Fishing Effort (No. of traps)	Catch/Unit effort (kg/trap)
1962	153	7,760	19.7
1963	125	8,650	14.5
1964	120	10,100	11.9
1965	112	12,860	8.7
1966	126	10,990	11.5
1967	110	12,035	9.1
1968	106	11,176	9.5
1969	96	13,500	7.1
1970	93	13,500	6.9
1971	104	13,580	7.7
1972	104	11,833	8.8
1973	129	11,833	10.9
1974 1/	51	6,000	8.5
1975	129	9,000	14.3
1976	123	7,659	16.1
1977	127	6,605	19.2

Source: Politicas de Desarrollo Pesquero (UNDP), 1979

1/ The 1974 data were omitted from the yield analysis

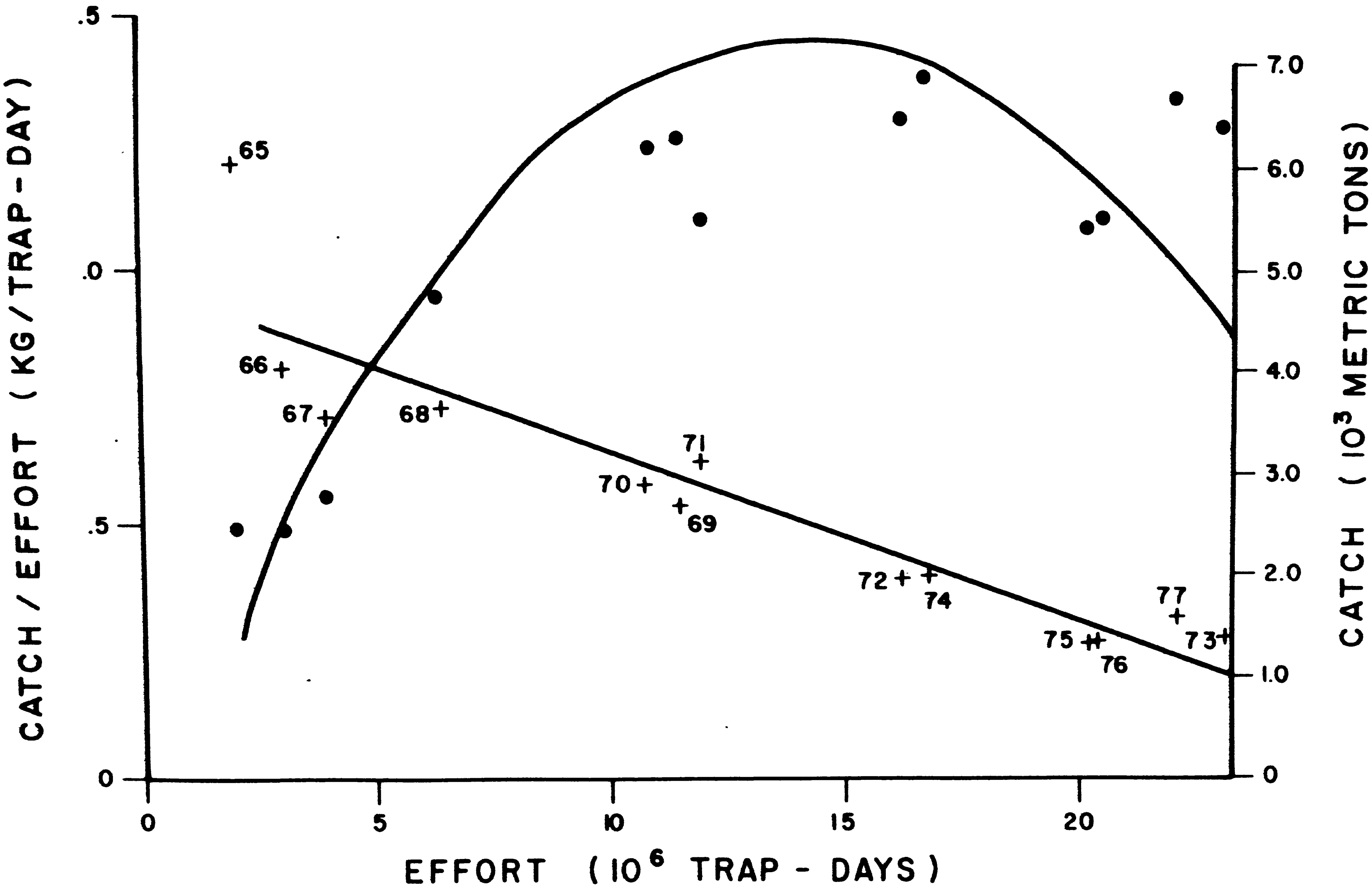


Figure 30 Linear regression of estimated 1965-1977 CPUE versus effort for spiny lobster (Panulirus argus and Panulirus laevicauda) harvested by the Brazilian fishery north of the equator and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1979a)

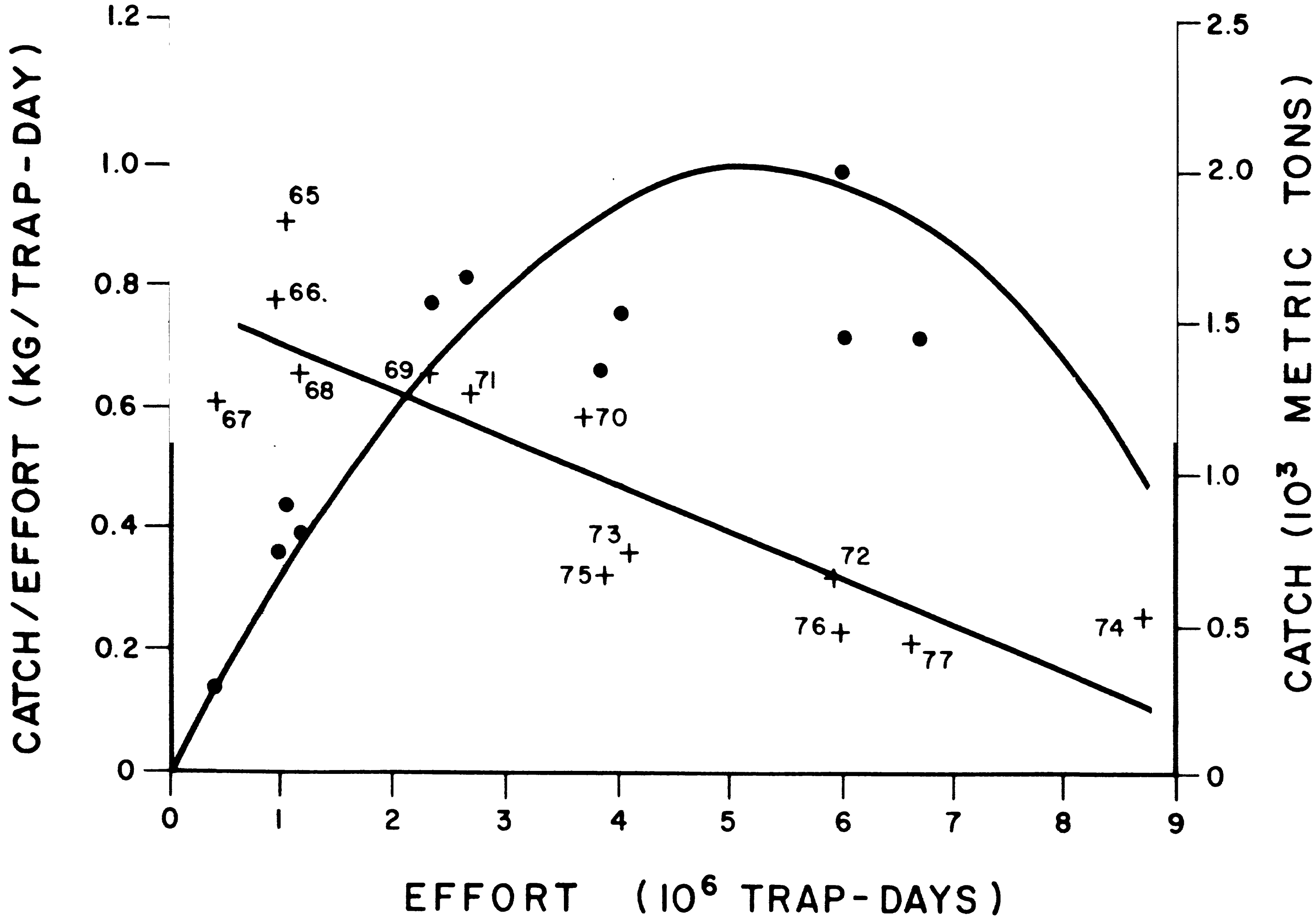


Figure 31 Linear regression of estimated 1965-1977 CPUE versus effort for spiny lobster (Panulirus argus and Panulirus laevicauda) harvested by the Brazilian fishery south of the equator and the predicted yield curve. Catch is in whole weight (Source: WECAF, 1979a)

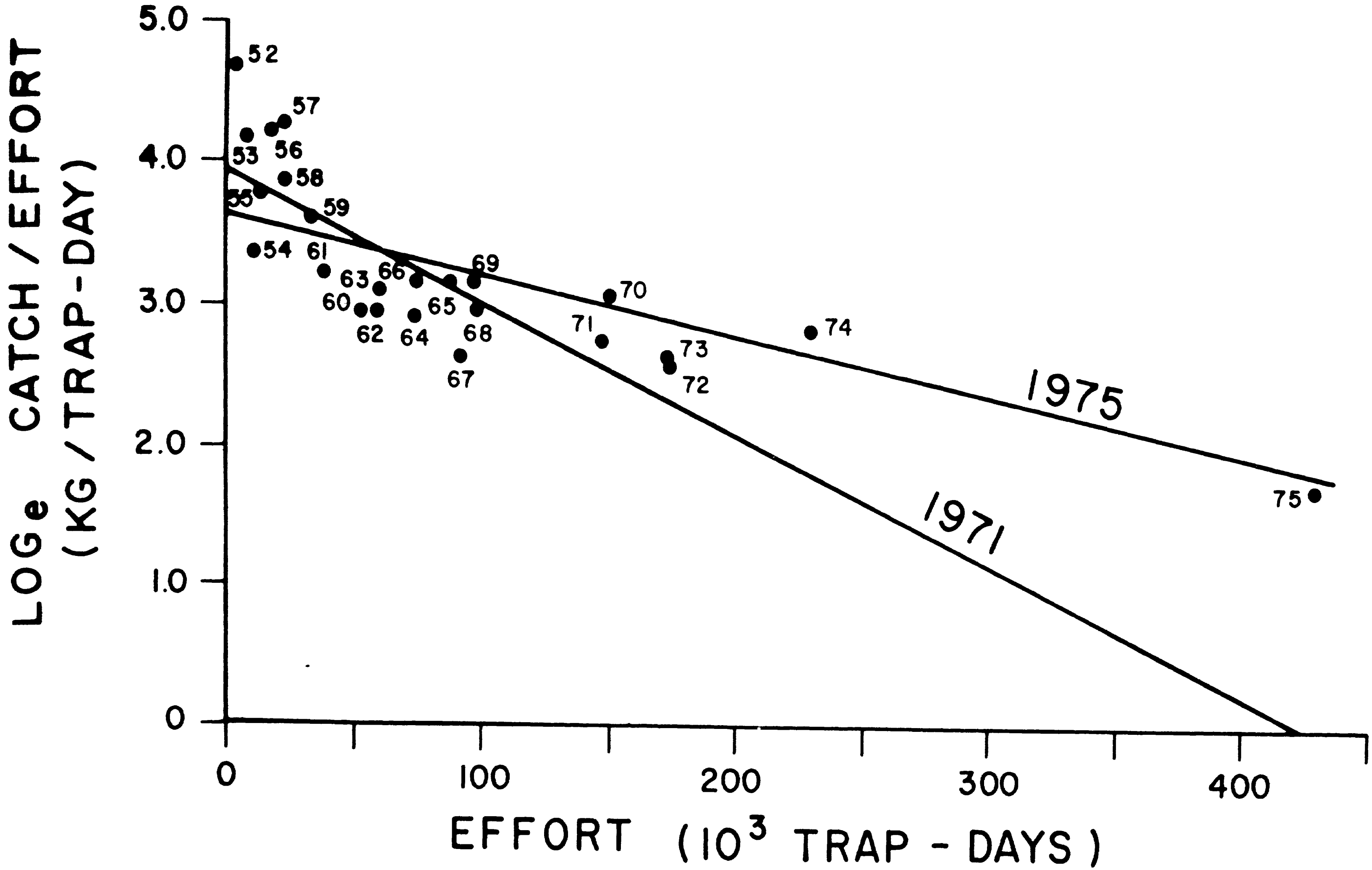
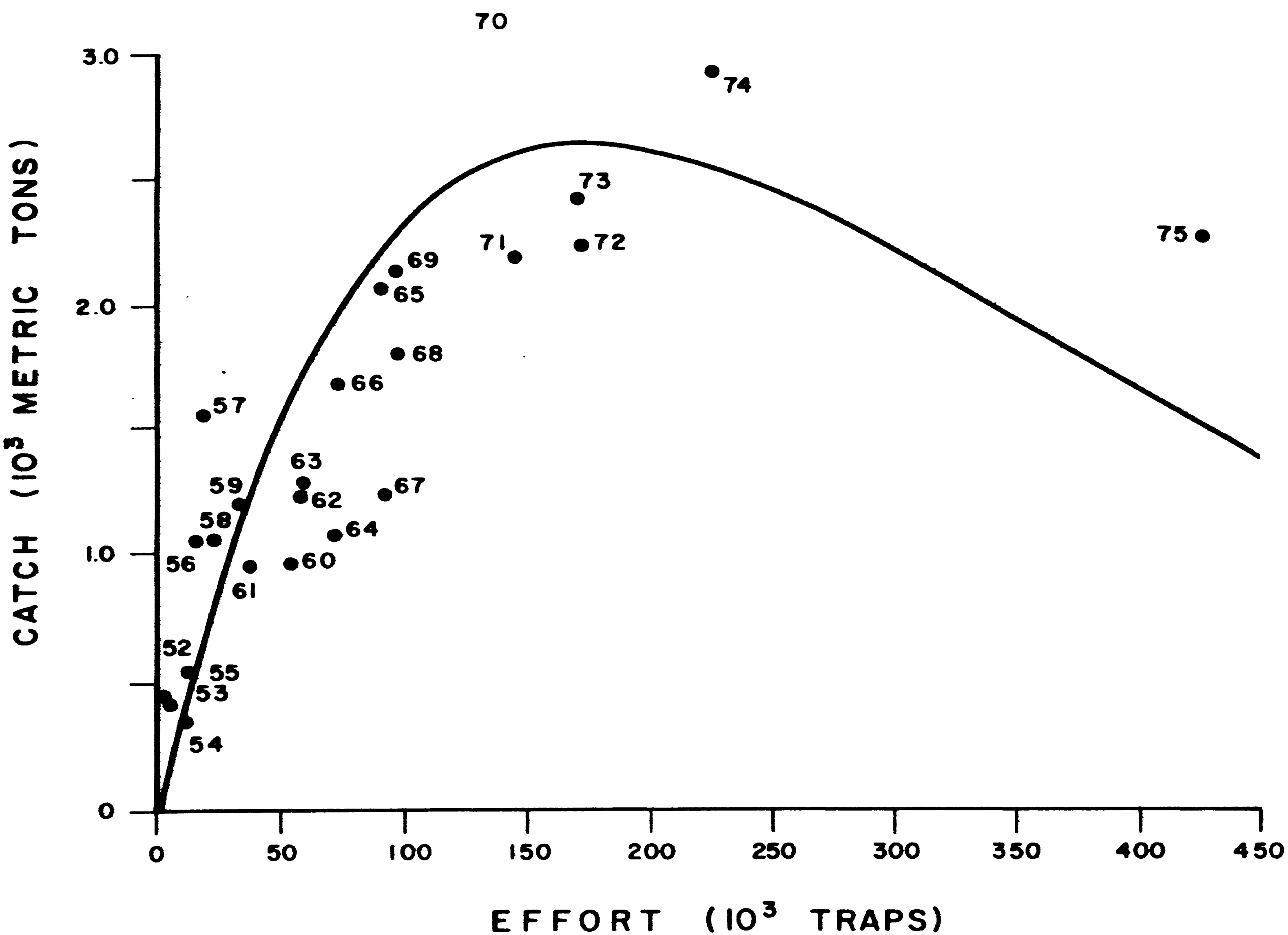


Figure 32 Exponential regressions of estimated CPUE versus effort for spiny lobsters harvested by the commercial fishery in Munroe County, Florida (U.S.A.) for the periods 1952-1971 and 1952-1975. Catch is in whole weight (Source: Gulf of Mexico and South Atlantic FMCs, 1979a)



<u>Figure 33</u> Annual estimated 1952-1975 catch (whole weight) and effort, and the predicted yield curve for the commercial spiny lobster fishery in Munroe County, Florida (U.S.A.) (Source: Gulf of Mexico and South Atlantic FMCs, 1979a)

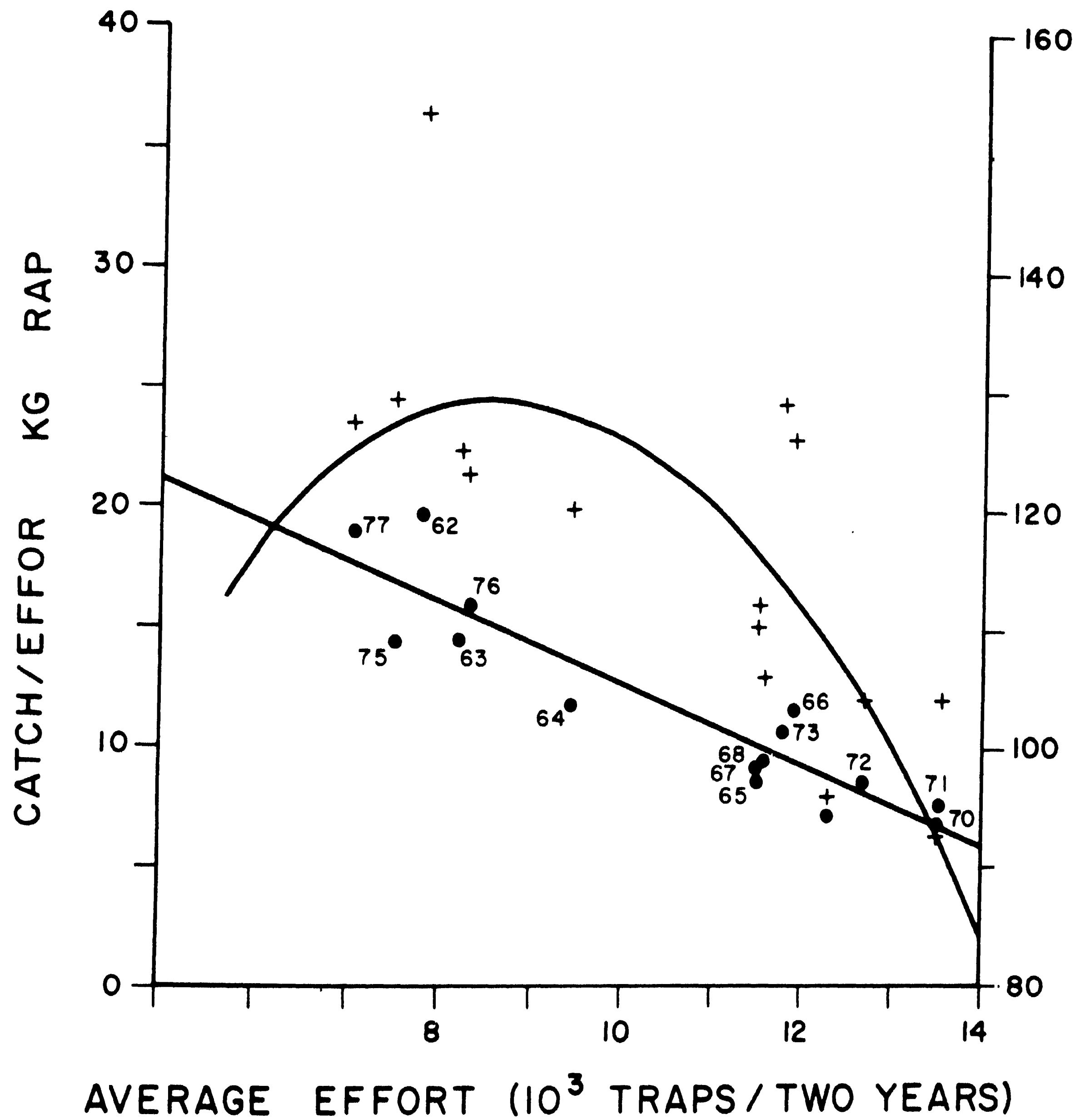


Figure 34 Linear regression of estimated 1962-1977 CPUE versus average effort for spiny lobster harvested in Los Roques Archipelago, Venezuela and the predicted yield curve. Effort was averaged over a two-year period and catch is in whole weight (Source: Politicas de Desarrollo Pesquero, 1979)

CHAPTER 9: CRABS

Reported commercial landings of crabs in the WECAFC region have fluctuated around 40,000 tons a year for the last 20 years (Table 4). The principal species is the blue crab (Callinectes sapidus). Blue crabs are harvested primarily in the U.S. (also in Mexico) and account for 75% of the current reported landings. Blue crab landings in the Western Central Atlantic represent about half of the total U.S. commercial production. This resource is probably underutilized, but no stock assessments have been attempted given the lack of effort data. Actual catch probably exceeds reported landings since this species is also harvested by recreational and subsistence fisheries. Deuel (unpublished data) estimated that 12,000 tons of crabs were harvested by U.S. recreational fishermen in the WECAFC area in 1975. Presumably most of this catch was blue crabs.

Additional species of commercial importance are the "siri" crabs (principally Callinectes danae) in Brazil, and stone crabs (Menippe mercenaria) in Florida. Munro (1974a) also observed significant catches of Mithrax spinosissimus, a large species of spider crab, in traps on the shallow, exploited reefs on the south coast of Jamaica. Assuming that 50% of the total reported Brazilian landings of crabs come from the northeast coast, i.e. within WECAFC waters (Paiva et al., 1971), production is currently between 5 and 6 thousand tons and was higher during the late 1960s and early 1970s.

U.S. landings of stone crabs increased from 150 tons in the early 1960s to nearly 1,000 tons (claw weight) in the 1977-1978 season. Cuban landings were first reported in 1975 and have reached nearly 2,000 tons in recent years. Small quantities of stone crab (100 tons or less in recent years) are also reported from the Dominican Republic. Some of the catch may be of a smaller species, Menippe nodifrons.

Most of the Callinectes crabs inhabit the shallow, inshore littoral zone and are abundant in estuaries. They are harvested by hand with a variety of gear and are also caught in pots, nets, with trotlines and in bottom trawls. The principal stone crab gear is a small, wooden lath pot.

Assessments

Gulland (1971) estimated a potential crab catch of 80,000-150,000 tons in the WECAFC region (excluding Brazil). Bullis et al. (1971) estimated 180,000 tons for the same area. Present catches are probably below the potential yield even when unreported sources are considered. The only unit stock assessment performed was for the Florida stone crab fishery (Gulf of Mexico FMC, 1979b).

Although stone crabs (Menippe mercenaria) range from North Carolina to Yucatan, the only U.S. fishery for this species is in Florida, principally on the west coast. Stone crabs harvested in Cuba presumably belong to a different stock or a completely different species (M. nodifrons). Commercial catch (claw weight) and effort (number of traps) data from western Florida were available for the period 1962-1978 (Table 69). Catch-per-unit-effort and effort data have been analysed with both linear and exponential surplus production equations (Gulf of Mexico FMC, 1979b). The following MSY estimates were increased by 20% to account for the unreported recreational catch:

Model	MSY (claw tons)	f_{MSY} (Number of traps)
Linear	660	155,000
Exponential	630	204,000

According to these results, the resource was over-exploited in 1976-77. Current effort is estimated at over 250,000 traps.

This assessment was not satisfactory. The fishery began to expand into deeper, offshore grounds in the early 1970s as indicated by large increases in catch and effort in recent years (Table 69). Neither the linear nor the exponential models fit the observed data very well (Figure 35) and the predicted yield

curves (Figure 36) only fit catch data prior to the 1972-73 season. The possibility that two stocks are being exploited by the same fishery cannot be ignored. Also, effort was measured as the number of traps reported and may significantly underestimate actual trap use. The state of Florida issued 535,000 trap permits in 1977-78, twice the number of reported traps (Gulf of Mexico FMC, 1979b).

The decline in catch-per-unit-effort and the expansion of the fishery into deeper water do suggest that the resource, at least in inshore waters, is heavily exploited. Sullivan (in press) reported a heavy fishing mortality (30-50%) of legal-sized crabs during a recent fishing season, but also noted that a large reserve of sub-legal size crabs was present on the fishing grounds. Any attempt to improve the assessment for this resource using growth and mortality estimates must consider the fact that crabs are returned to the water once their claws are removed to regenerate new ones. Savage et al. (1975) estimated the percentage of regenerated claws which are harvested annually to be less than 5%.

Table 69

1962-1978 catch, fishing effort and catch-per-unit-effort data for the Florida west coast stone crab fishery, by fishing season. Catch is in claw weight (equal to one-half whole weight)

Season	Catch (tons)	Effort ('000 traps)	CPUE (kg/trap)
1962-63	135	14.6	9.5
1963-64	160	15.0	10.7
1964-65	160	21.0	7.7
1965-66	205	19.7	10.5
1966-67	180	43.2	4.3
1967-68	250	39.3	6.4
1968-69	275	55.9	4.9
1969-70	320	36.0	8.9
1970-71	385	60.8	6.4
1971-72	430	73.7	5.9
1972-73	410	113.3	3.6
1973-74	570	143.0	4.0
1974-75	455	159.1	2.9
1975-76	525	193.2	2.8
1976-77	660	213.8	3.1
1977-78	955	264.3	3.7

Source: Gulf of Mexico FMC, 1979b

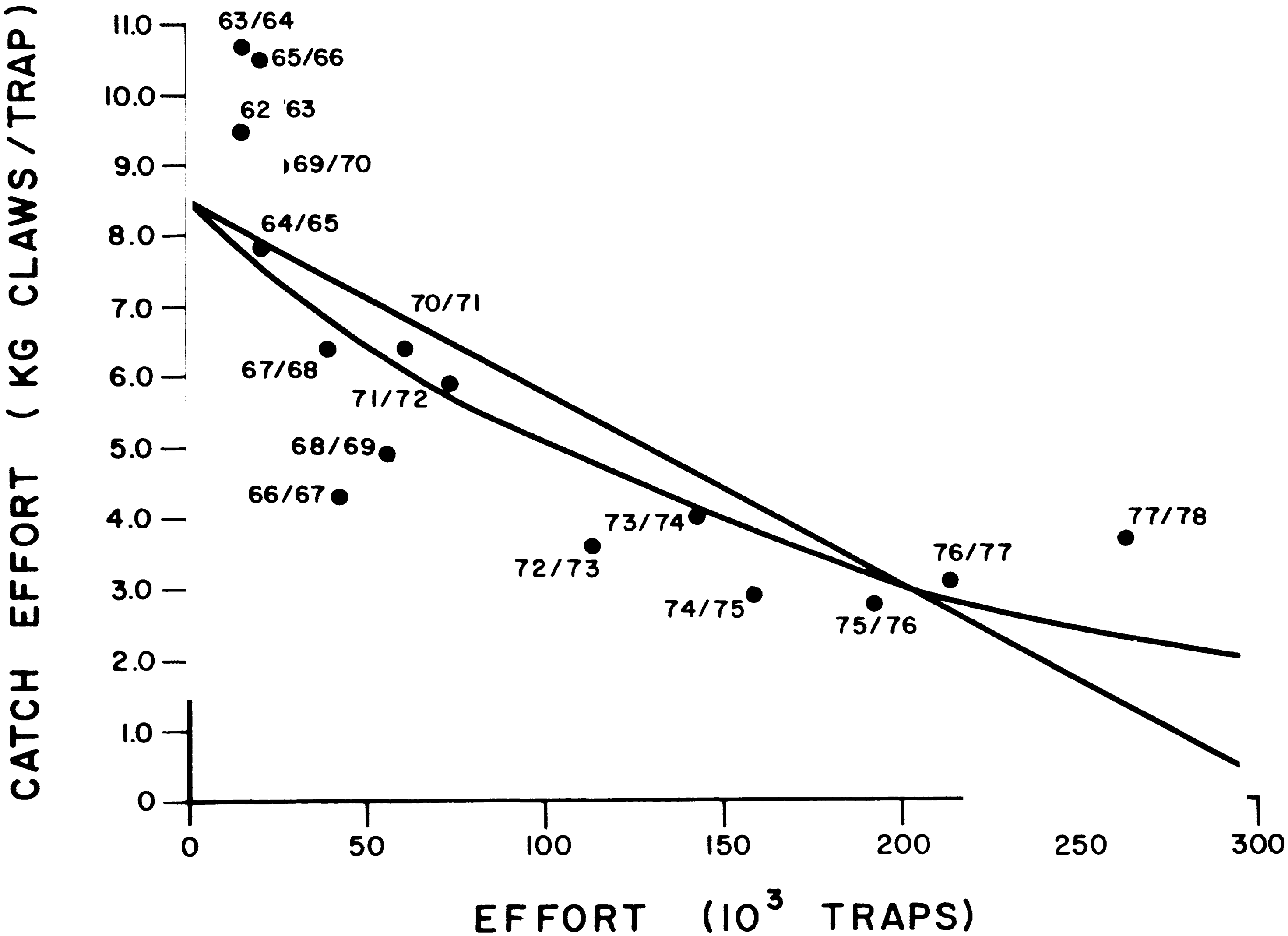


Figure 35 Linear and exponential regressions of estimated seasonal 1962/63-1977/78 CPUE versus effort for the commercial U.S. Florida stone crab (Menippe mercenaria) fishery. Catch is in claw weight (Source: Gulf of Mexico FMC, 1979b)

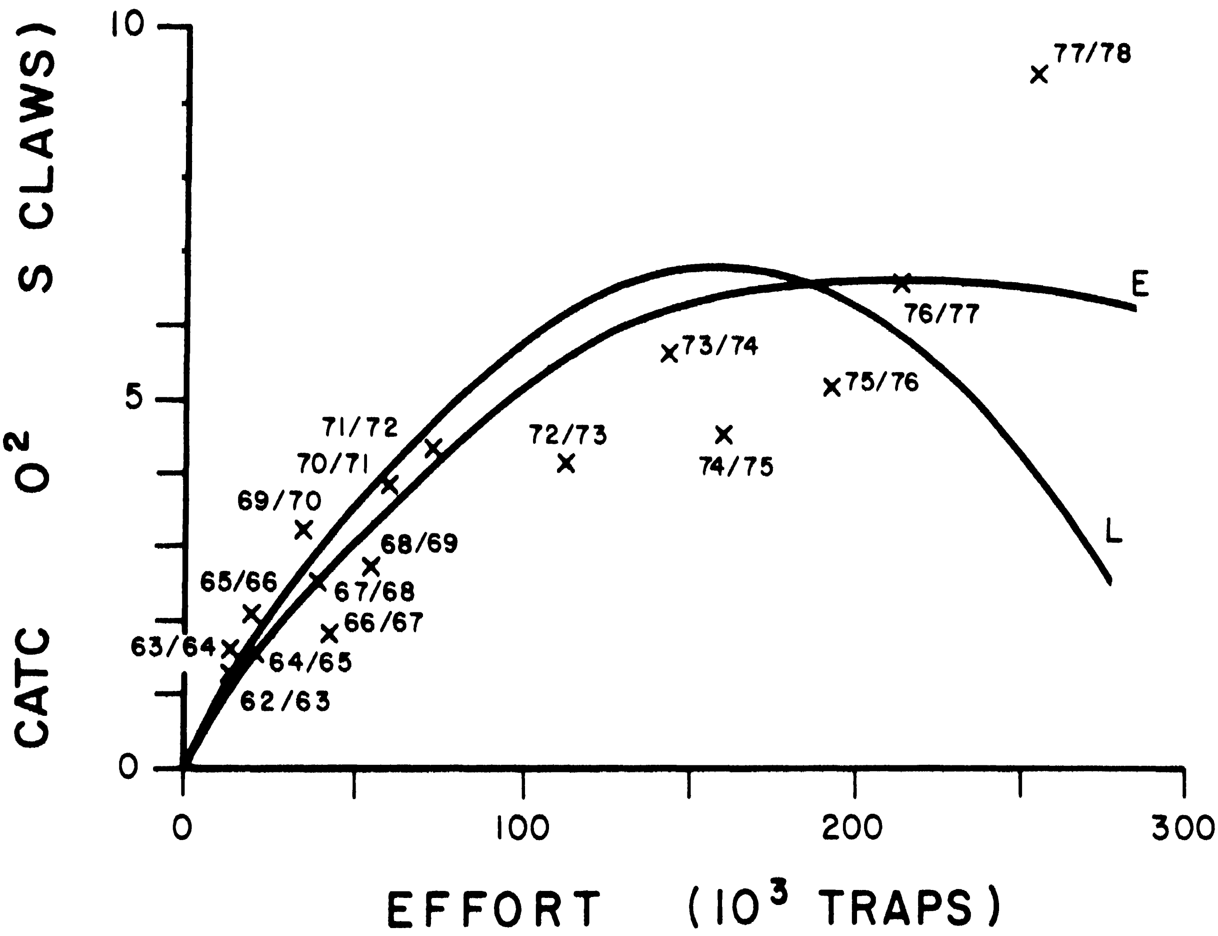


Figure 36 Annual estimated 1962/63-1977/78 catch (claw weight) and effort and yield curves predicted by the exponential (E) and linear (L) surplus production models for stone crabs (Menippe mercenaria) harvested by the U.S. Florida commercial fishery (Source: Gulf of Mexico FMC, 1979b)

CHAPTER 10: MOLLUSCS

A great variety of molluscs are harvested in the Western Central Atlantic. Fischer (1978) listed 38 species of edible bivalves, 4 chitons and 24 gastropods and Voss (1973) mentioned 10 utilized species of squid and octopus. Mollusc fisheries are conducted at both the industrial and artisanal levels, but the majority of the harvested species are collected by hand and not reported. Reported landings in 1978 totalled 260,000 tons whole weight in statistical area 31 (Table 4), but probably under-estimated actual harvest by a wide margin. 36,000 tons of assorted shellfish (excluding crabs) were reportedly harvested by U.S. recreational fishermen in WECAFC waters in 1975 (Table 6). Some species (oysters, ark clams) are canned, while others (squid, octopus, conch) are frozen.

Molluscan resources in the Western Central Atlantic are consumed locally and also support a valuable export trade. Aside from several estimates of shellfish density and biomass on localized fishing grounds, no assessments have been conducted.

Bivalves

Bivalves account for nearly all the reported commercial mollusc landings in the area (Table 70). Directed fisheries for oysters, scallops and hard clams exist in the U.S., for ark clams in Venezuela, and for oysters in Mexico. The majority of the reported landings (72%) are American oysters (*Crassostrea virginica*) which are dredged or collected with tongs in shallow hard bottom areas less than 10 m deep in the United States and northeastern Mexico. Mangrove oysters (*Crassostrea rhizophorae*) are collected by hand from mangrove roots throughout the Caribbean islands and from Mexico to Brazil. Neither the actual harvest nor the resource potential of mangrove oysters is known, although they are a candidate for aquaculture.

A number of species of scallops are harvested. Two sub-species of the bay scallop (*Argopecten irradians*) are collected in coastal lagoons and bays from north of Cape Hatteras through the Gulf of Mexico to Colombia. Commercial harvest of this species is insignificant. Exploitable concentrations of the calico scallop (*Agropecten gibbus*) have been located on offshore grounds (20-80 m) in eastern and northwestern Florida and North Carolina (Cummins, 1971), although it is found throughout the region. This species supports a small commercial fishery in the U.S. Nearly 10,000 tons were harvested with trawls and dredges in 1978 (Table 70). Four species of scallops are harvested by trawlers in Venezuela (Salaya and Penchaszadeh, 1979). A small directed trawl fishery for scallops, principally *Pecten papyraceus*, developed in eastern Venezuela in 1972, but production has declined since the closing of primary grounds to trawling in 1973. The same authors reported that scallops (*Pecten laurenti*) are harvested incidentally by shrimp trawlers in Colombia.

Because calico and bay scallops are short-lived (two years or less), grow rapidly, mature early and have a high reproductive potential. Populations are therefore subject to wide and unpredictable fluctuations in abundance. At the same time, biomass which is not harvested is lost via natural mortality. Below a certain minimum density and average size, calico scallops are not economical to harvest, a fact which discourages over-exploitation. Scallop resources in the Westen Central Atlantic are assumed to be underutilized.

A sizeable commercial and artisanal dredge fishery for ark clams (*Arca zebra*) is conducted in Venezuelan shelf waters east of Isla Margarita. The fishery opened in 1940. Reported average annual landings increased from 3,800 tons in 1965-69 to 9,150 tons in 1970-77 (Table 4). 1978 landings exceeded 40,000 tons (Table 70). Independent estimates of biomass on the largest bank (El Tirano) obtained from catch data and a tagging study were 34,000-42,500 tons (Politicas de Desarrollo Pesquero, 1978). This species is distributed in shallow water throughout most of the region. If sufficient markets could be developed, the ark clam fishery could presumably be expanded to other countries.

Two species of hardshell clam (*Mercenaria* spp.) are harvested commercially in the southeastern U.S. and western Florida. One sub-species of *M. mercenaria* is found on the U.S. Atlantic coast north of Florida and another from Texas to Campeche, Mexico. *M. campechiensis* is found principally in offshore coastal waters on the Atlantic coast and on intertidal flats and in protected lagoons and bays from Florida to Yucatan.

Gastropods

According to Fischer (1978), the most important edible gastropod resources in the Western Central Atlantic are the queen conch (Strombus gigas) and the West Indian top shell (Cittarium pica). Top shells are not harvested commercially and no catch estimates are available. Conchs represent an important commercial resource. S. gigas is abundant on turtle grass flats in the Caribbean islands, southern Florida, Bermuda and the coasts of Central and South America in 1-30 m of water and can be easily collected by hand, either from small boats or by divers. Other species of conch (or whelk) which are also collected by hand or incidentally in shrimp trawls include Strombus costatus, Melongena melongena, and Busycon perversum (Fischer, 1978).

Reliable production figures do not exist for conchs. Stevely (1979) reported that U.S. imports of frozen conch meat doubled between 1970 and 1975 and have levelled off in recent years despite a continuing rise in prices and that production in Belize declined by 50% between 1972 and 1977. Given the ease with which conchs can be harvested, it is not surprising that the resource may be overexploited in areas of more intense fishing pressure.

Cephalopods

Fischer (1978) listed 83 species of squid and 27 species of octopus in FAO statistical area 31. Reported landings estimates from area 31 (Table 70) were only 3,500 tons in 1978. Less than 1,000 tons were reported for all of Brazil in 1978 (FAO, 1979). Most of the reported landings are for octopus harvested in Mexico. The actual catch of octopus is probably much higher. Squid are caught incidentally in shrimp trawls and represent a large resource which is, for all practical purposes, completely unexploited at present. The octopus resource is also presumed to be very large, although population sizes are limited by the amount of available bottom habitat. Gulland (1971) suggested a total potential of more than 100,000 tons of cephalopods in area 31, possibly as much as 0.5-1.0 million tons, but not as high as 2 million tons. Development of expanded squid and octopus fisheries requires market outlets; frozen, canned and dried products are currently produced by countries outside the WECAFC region and constitute valuable export commodities.

Since squid and octopus species are not distinguished in landings statistics, it is difficult to identify which species are currently exploited. Voss (1973) reported that small quantities of Loligo pealei, Lolliguncula brevis and Loligo plei are caught incidentally in bottom trawls in the southeastern United States and Gulf of Mexico. There is a small directed fishery for squid on Campeche Bank. Three species of Illex which occur in shelf waters of the Western Central Atlantic are harvested in other areas: Illex illecebrosus and Illex oxygonius are more northern species, while Illex coindetti is more widespread and seems to have a high yield potential (Fischer, 1978). There are also a number of larger, cosmopolitan oceanic species which occur in the Western Central Atlantic but are not harvested. Another species which is found in coral reef areas is Sepioteuthis sepioidea. Other species of this genus are fished extensively in the Indo-Pacific (Fischer, 1978).

Rathjen et al. (1979) summarized the results of exploratory squid fishing with bottom trawls, squid jigs and dipnets (with night lights) in the western Gulf of Mexico. The best catches were made in the Gulf of Campeche and on the western edges of Campeche Bank. Principal species caught were L. pealei, L. plei and L. brevis. These three species showed fairly well-defined depth preferences. These authors failed to observe any feeding or spawning concentration of squid in the area. Squid are very active and undergo seasonal inshore-offshore and vertical diurnal migrations. Commercial exploitation would require gear such as mid-water trawls and lampara nets with night lights.

Squid are typically short-lived, grow rapidly, have high mortality rates and are prolific spawners. Populations are subject to abrupt changes in seasonal and annual abundance so that assessments based on conventional equilibrium yield models therefore do not seem very feasible.

Octopus are caught by hand (hook, poles, spears) and in clay pots. The best known species, Octopus vulgaris, inhabits a variety of bottom types. Landings for this species reported from Mexico are probably, in fact, Octopus mayo. Landings of over 6,000 tons were reported in Mexico in 1977. Other species which are common include O. macropus and O. briarius (Fischer, 1978). Octopus live for 1-2 years. Female octopus produce a single brood which they protect until the eggs hatch. The males die after mating and the females after the eggs are hatched.

Table 70

1978 nominal catches of bivalve molluscs, conchs and cephalopods from the Western Central Atlantic ocean (FAO Statistical Area 31)

	Species or Family	Catch by Country* ('000 tons)		Total
Bivalve Molluscs:				
American oyster	*Crassostrea virginica*	U.S.A.	148.0	
		Mexico	33.5	181.5
Mangrove oyster	*Crassostrea rhizophora*	Cuba		2.9
Calico scallop	*Argopecten gibbus*	U.S.A.		9.5
Bay scallop	*Argopecten irradians*	U.S.A.		4.0
Other scallops		U.S.A.		4.0
Ark clams	*Arca zebra*	Venezuela		41.3
Hard clams	*Mercenaria mercenaria* *Mercenaria campechiensis*	U.S.A.		5.5
Venus clams	Veneridae	Mexico		1.7
Mussels	*Perna perna*	Venezuela		1.2
Conchs, Whelks	Melongenidae, Strombidae	Mexico		4.8
Cephalopods:				
Squid	*Loligo* spp.	-		0.7
Octopus	*Octopus vulgaris*	Mexico		2.3
	Octopodidae	Venezuela		0.5
TOTAL :				260.0

Source: FAO Yearbook of Fishery Statistics, Vol. 46

* Principal reporting countries only

CHAPTER 11 : SUMMARY

Total annual commercial landings of 1.5-1.7 million tons were reported for the Western Central Atlantic between 1974 and 1977. The 1978 catch (2 million tons) represented 2.8% of the total world production. Menhaden account for nearly half of all reported landings in the WECAFC region. Total landings of all other species have remained stable at about 1 million tons since at least 1964. Major producing countries are the U.S., Mexico, Venezuela, Brazil and Cuba. These five countries produced 94% of the total reported 1978 catch. Estimates of fish discards from shrimp trawlers increased current harvest figures by an additional 1.0 to 1.5 million tons. In addition to discarded groundfish, substantially underutilized resources in the region include a number of small coastal pelagic speices, squid, sharks and seabob shrimp.

Groundfish

Reported commercial landings averaged about 200,000 tons a year in recent years, representing 10% of the total regional landings. An additional 80,000 tons was estimated for the U.S. recreational fishery in 1975. As much as 80% or more of the total estimated groundfish catch in the WECAFC area is currently discarded at sea. A conservative estimate of the quantity of groundfish discarded by shrimp trawlers (1 million tons a year) was based on fish/shrimp discard ratios which varied between 3.0 and 20.0 for different areas. Principal fishing grounds are located on the continental shelf in the northern Gulf of Mexico, on Campeche Bank and in Venezuela and northeastern South America.

Assessments of groundfish stocks in the WECAFC region have been primarily based on trawl surveys conducted during the last 20 years. Procedures proposed by Klima (1976) for adjusting observed catch rates to account for the capture efficiencies of different trawls were adopted in this report. Maximum potential yield (Y_{max}) was calculated from standing stock estimates by means of the yield equation $Y_{max} = 0.5$ ZB (Gulland, 1971). Estimates were very approximate since: (1) biomass (B) estimates were based on highly variable catch rates, and (2) common mortality estimates were applied to large numbers of species and were not known with any certainty. Total mortalitiy (Z) rates ranged from 0.50 to 0.85.

The total estimated standing stock of groundfish on continental shelves in the entire region (excluding Central America) was 6.0 to 9.7 million tons and the total potential yield was 2.0-3.2 million tons. Total catch was estimated to be 1.3-1.8 million tons, including shrimp discards and U.S. recreational landings. According to these estimates, 55-65% of the maximum potential groundfish yield is currently being harvested and only 6-10% is directly utilized. Clearly, the greatest source of increased production in the WECAFC area which is readily accessible to existing capture techniques is the 1.0 to 1.5 million tons of groundfish which is presently discarded at sea. However, until such time as it becomes economically feasible to retain and process this fish, it will continue to be wasted.

Grounds with the greatest potential for increased groundfish production seem to be Campeche Bank and the northern and northeast coasts of South America, although discards in these areas may be under-estimated. According to available catch and Y_{max} estimates, harvest in the Guianas and Brazil could be increased three to five times (i.e. by an additional 450,000-950,000 tons) beyond present catch without endangering the stocks. Increases of 130,000-180,000 tons might be expected from the Central American and Colombian/Venezuelan coast, except that most of the coralline shelf east of Honduras and Nicaragua is too rough for trawling. The possibility of increased production on Campeche Bank is suggested by the fact that 75,000 tons of groundfish were harvested by Soviet trawlers in 1972 and 1975. Extensive trawl surveys in the Gulf of Mexico indicate that current harvest may be slightly below Y_{max}.

Regardless of the fact that the harvest of groundfish resources in the Western Central Atlantic may be modestly increased, increased production will require a more complete utilization of discards from existing shrimp fleets, a development which in turn depends on an improved market demand for discarded groundfish. Deep water groundfish resources (e.g. hake) are presently unexploited and could support substantially increased catches if proper harvest techniques are applied.

Sharks

Sharks are not presently subject to any large-scale commercial fishery in the WECAFC area, although annual catches probably exceeded the 12,000 tons a year reported during 1974-1978. Bullis et al. (1971) estimated a total standing stock of 600,000 tons in statistical area 31. Since sharks have a very low reproductive potential and recruitment is strongly dependent on stock size, the standard form of the yield equation (Gulland, 1971) was modified for the assessment of shark resources in the U.S. Gulf of Mexico (Gulf of Mexico FMC, 1979) to $Y_{max} = 0.25\ MB_0$. An average M=0.30 was used for all shark assessments. Biomass estimates for large and small sharks and for skates and rays in inshore and offshore waters were based on very approximate average catch rates from a variety of fishing gears reported by Bullis et al. (1971). Total Gulf of Mexico MSY was estimated to be 16,000-25,000 tons, 80% for inshore species and 50% of this for small sharks. Total catch (all sources) in the U.S. Gulf of Mexico in 1978 was estimated to be 7,600 tons. Individual species of large sharks which are believed to be in danger of over-exploitation in inshore waters of the Gulf are bull shark, lemon shark and dusky shark. A conservative MSY of 45,000 tons was estimated for all species in the entire WECAFC area.

Reef fish

Reef fish resources are exploited in areas of rough bottom on continental shelves and on island reefs and offshore banks with pots, handlines and longlines throughout the WECAFC area. Because this resource is composed of a large number of species and is exploited predominantly by small-scale fishermen who land fish in remote locations, reliable catch and effort statistics are only available for Cuban, Mexican, U.S. and Brazilian commercial fleets which primarily harvest snapper and grouper on the continental shelves. Reported commercial catches of grunts, snappers and groupers averaged 72,000 tons a year in statistical area 31 during 1970-1978, and Munro (1977) estimated a 1968 catch of 100,000 tons from island shelves and offshore banks in the Caribbean and the Bahamas. U.S. recreational landings of 30,000 tons were estimated for 1975 (Deuel, unpublished data). Reef fish resources in deeper water near the shelf edge of islands and banks in the Caribbean are reportedly underutilized.

An average catch rate for all demersal reef species in the Caribbean (1 ton/km^2) produced a rough Y_{max} estimate of 280,000 tons from insular shelves and offshore banks. Although actual catch is probably considerably higher than the 100,000 tons reported by Munro, there is apparently a potential for increased production, especially in deeper water along the shelf edge in locations where traditional fishing activity has been minimal.

Trawl survey data have been used to estimate the standing stock and potential yield of reef species in the southeastern U.S. and on Campeche Bank, but since a trawl is a poor sampling gear to deploy in areas of rough bottom, these estimates are not very reliable. Yield/recruit models were applied to individual species in the same two locations. In the southeastern U.S., growth and mortality rates were estimated for seven reef species (Huntsman et al., MS.). For all species, a small increase in yield was predicted for fishing mortality rates greater than 0.30, the approximate prevailing rate. This analysis provided a basis for recommending that yields not exceed the 1977 production of 7,000 tons (South Atlantic FMC, 1978). A Y/R model was applied to Epinephelus morio, the principal species exploited on Campeche Bank, by Mélo (1976), who predicted that yield could be doubled if the age-at-first-capture was increased from two to six years. Present catch equals about 20,000 tons.

Surplus production models have been applied to catch and effort data in the U.S. Gulf of Mexico (Gulf of Mexico FMC, 1979a) and northern Brazil (Programa de PDP do Brasil, 1978). Attempts to estimate MSY in the Gulf from commercial and recreational catch and effort data were inconclusive. A potential yield estimate of 40,000 tons for all reef species was obtained by applying an average catch rate of 1 ton/km^2 to areas of rough bottom in the Gulf. Present catch was estimated between 15,000 and 20,000 tons and is composed primarily of snapper and grouper. However, reductions in the mean catch per vessel and size-at-capture in the U.S. commercial catch in recent years suggest that snapper/grouper stocks may be in danger of overexploitation. Other reef species which are not harvested in large quantities by handlines, longlines or incidentally by shrimp trawlers are underutilized.

The assessment of the Lutjanus purpureus resource in northern Brazil was based on historical catch and effort data from the early years of the fishery to the present (1966-1977) and produced a good agreement between predicted and observed yields. Estimated MSY was 5,800 tons, approximately equal to 1975 and 1976 landings, but lower than 1977 landings by about 1,000 tons. The reported 1977 fishing effort was twice the predicted f_{MSY}.

Coastal pelagics

With the exception of approximate Y_{max} estimates based on standing stocks estimated from egg and larval surveys in the eastern Gulf of Mexico and Y/R assessments of king and Spanish mackerel stocks in U.S. and Mexican waters, no reliable estimates of the potential yield of coastal pelagic species in the WECAFC area were available. Nevertheless, stocks of smaller carangid and clupeid species have frequently been described as the greatest underutilized resource in the region. Standing stock estimates could be as high as 10 million tons (Bullis, et al., 1971) and potential yields (including menhaden) have been estimated at 2.5-3.2 million tons (Gulland, 1971). Large-scale exploitation of these resources will not be economically feasible, however, until more efficient harvest techniques are developed and additional processing facilities are available. These resources would be used primarily to produce fish meal and oil.

Reliable catch statistics do not exist for most of the smaller, underutilized pelagic species in the region. The major directed fishery is for Spanish sardine (Sardinella aurita) in Venezuela; reported landings averaged 40,000 tons a year between 1961 and 1975. Potential yield for this fishery probably does not exceed current production. Reported landings of mullet, jacks and mackerel totalled 75,000 tons in 1978. Reintjes (1979) speculated that less than 10% of the actual catch of pelagic species in the region is reported.

Standing stock estimates based on 1971-1974 egg and larval surveys off the west coast of Florida (Houde et al., 1971) were highly variable, but three clupeid species (Opisthonema oglinum, Etrumeus teres, and Harengula jaguana) and one carangid (Decapterus punctatus) were within the 100,000-700,000 ton range and the standing stock of Spanish sardine is believed to exceed 200,000 tons. The total standing stock of pelagic fishes in the area is 1.5-3.0 million tons and, assuming natural mortality rates of 0.40 and 1.0, Y_{max} totalled 240,000-560,000 tons.

Yield-per-recruit assessments of Spanish and king mackerel (Scomberomorus maculatus and S. cavalla) were based on a range of probable parameter values (Gulf of Mexico and South Atlantic FMCs, 1979). Recruitment was estimated from inferred population sizes, and based on the "best" available parameter estimates in 1975, MSY was calculated to be 17,000 tons for king mackerel and 12,500 tons for Spanish mackerel. Estimated 1975 U.S. commercial and recreational catches for these two species were 14,000 and 9,300 tons, respectively, suggesting that neither stock was over-exploited in 1975.

Y/R analyses for Spanish mackerel on the Mexican coast produced apparently contradictory results depending on the parameter estimates which were used. Klima (1976a) concluded that the stock was nearly fully exploited, while Doi and Mendizabal (1979) reported that yield could be doubled by increasing effort as long as the age composition remained the same.

Menhaden

Landings of 914,000 tons of menhaden in 1978 accounted for 46% of the total reported production in the WECAFC area. A single stock of Atlantic menhaden (Brevoortia tyrannus) is exploited along the east coast of the U.S. Landings declined dramatically in 1963 following the heavy exploitation of unusually abundant 1955, 1956 and 1958 year-classes and have stabilized since 1970, averaging 315,000 tons a year. Twenty-three percent of the 1975-1978 catch was harvested in the WECAFC area, i.e. south of Cape Hatteras. A record high catch of 712,000 tons was recorded in 1956. Gulf menhaden (Brevoortia patronus) landings have generally increased since the 1970s and reached high records of 800,000 tons in 1978 and 1979. The future of the Gulf menhaden fishery is uncertain.

Considerable biological information has been compiled for both species, but particularly for Atlantic menhaden. The assessment of the Atlantic stock represents the most complete resource evaluation which has been conducted in the region. MSY has been estimated with surplus production models, a dynamic pool model and an empirical multiple regression equation which includes environmental variables. A surplus production model was originally fitted to 1955-1969 catch and effort data (Schaaf and Huntsman, 1972) and later updated to include data through 1973 (Schaaf, 1975). Effort was estimated as the number of vessel-weeks and was standardized first to a 1969 vessel-week and later to a 1971 vessel-week. This report extended the surplus production model to include data through 1979, using unadjusted 1972-1979 effort data. MSY estimated from these three analyses only varied by 60,000 tons (560,000-620,000 tons), but was significantly higher than the MSY of 380,000 tons predicted by the dynamic pool model (Schaaf and Huntsman, 1972). The lower estimate was believed to be more reliable since it was based on average recruitment rates. Although current yields may not exceed MSY, current effort is much greater than f_{MSY} and even exceeds the maximum fishing mortality rate which the population can sustain without eventually declining to zero. Increased catches could presumably be taken if effort were reduced to take advantage of future large year-classes by maintaining a spawning stock of optimum size.

A spawner-recruit model (Nelson et al., 1977) was developed for predicting recruit survival for a given total allowable catch. Surplus yield was calculated under conditions which would maintain four spawning ages in the population. Based on the estimated 1955-1971 survival rates and on optimum spawning stock size predicted by the Ricker stock-recruitment function, allowable catch averaged 419,000 tons a year. The most significant variable in this model was the transport of larvae into inshore nursery grounds.

Reliable MSY estimates do not exist for the Gulf menhaden fishery. A series of surplus production models have been fitted to catch and effort data dating from 1946 (Chapoton, 1972; Schaaf, 1975; Klima, 1976, and this report), but predicted MSY increased from 430,000 tons to 550,000 tons with the addition of up-dated information. The predicted yield curve does not fit the observed data very well, especially data from recent years, and no data were available for the right-hand side of the curve. Effort was measured as the number of vessel-ton-weeks and was not standardized since it was assumed that vessel size was related to capture efficiency. Although 1978-1979 landings were very high, effort did not increase beyond the 1975-1977 level.

Annual yield forecasts for both fisheries (Schaaf et al., 1975) were based on empirical multiple regression equations which require historical catch and effort data and effort predictions for the upcoming year. These forecasts have failed to account for variations in year-class strength and have been only moderately successful.

Shrimp

Reported commercial landings of shrimp in the WECAFC area have averaged 187,000 tons since 1970. An additonal unreported 30,000 tons a year may be harvested by recreational, artisanal and bait fisheries. Over 90% of the reported catch is composed of Penaeus species which are trawled on the continental margins of the southeastern U.S., the Gulf of Mexico and northern and northeast South America. Over half of the reported catch is from the northern Gulf of Mexico.

Most assessments have been based on historical catch and effort data and are severely handicapped by the fact that production is primarily related to recruitment and not to stock size or fishing effort. Recruitment is affected principally by environmental variables (temperature and salinity) in estuarine nursery grounds, and populations are short-lived and have little opportunity to reach equilibrium with the environment or with fishing effort, yet the surplus production model is an equilibrium model and does not account for changes in environmental conditions. Also, most data were compiled after the fisheries were already established and catches had stabilized, were not collected for individual species, and do not account for changes in capture efficiency with time. Unit fisheries have been defined arbitrarily on a geographic basis, ignoring the probability that the same stock may be harvested simultaneously in adjacent areas.

Surplus production models have been applied to catch and effort data collected from geographically defined unit fisheries in the U.S. Gulf of Mexico, Mexico, Nicaragua, Colombia, Venezuela and the Guianas and northern Brazil (Gulf of Mexico FMC, 1980; WECAFC, 1978, 1979 and 1979a). In all cases, estimated MSY values were equal to or slightly greater than observed yields, but, for the reasons stated above, these estimates were not reliable.

Yield-per-recruit models were also used to assess pink shrimp (Penaeus duorarum) and brown shrimp (Penaeus aztecus) populations in the U.S. Gulf of Mexico (Gulf of Mexico FMC, 1980) and, in both cases, predicted overexploitation. Estimates of weekly natural mortality rates for pink shrimp by various authors were highly variable; results were based on minimum M values (M 0.1) and average growth estimates, even though growth varies by sex and time of year. Fishing mortality rates were estimated by the swept area technique.

A production equation (Griffin and Beattie, 1978) which incorporates environmental variables predicted a MSY of 95,000 tons for all species of shrimp caught by commercial vessels in the U.S. Gulf of Mexico. This estimate was similar to MSY estimates obtained from surplus production models which ignored environmental variables (100,000 tons and 81,000 tons). The average annual 1963-1979 commercial catch of brown, white and pink shrimp in the U.S. Gulf of Mexico was 87,000 tons; maximum catch reached 118,000 tons in 1977. Reported commercial landings of other species exceeded 6,000 tons in 1979. The production equation correlated commercial catch with temperature, river discharge and fishing effort and predicted 82% of the annual variance in brown shrimp harvest during 1963-1975. In addition, bioeconomic simulation models have been successfully applied to the brown shrimp fishery off the Texas coast (Grant and Griffin, 1979) and to the pink shrimp fishery in southwest Florida (NMFS, 1979a). In the former case, simulations incorporating changes in recruitment confirmed the fact that the dynamics of harvest ultimately depend on environmental conditions which affect recruitment.

Royal red shrimp (Pleoticus robustus) are exploited in deep water in Florida and near the Mississippi River delta. This species is currently underutilized, as indicated by the analysis of catch and effort data from three fishing grounds and standing stock estimates inferred from trawl surveys. Seabob shrimp (Xiphopenaeus kroyeri) and rock shrimp (Sicyonia brevirostris) are harvested incidentally in shallow water with the penaeid species. No reliable estimates of resource potential were available for these species, but both are under-utilized. The biomass of unexploited seabobs is probably considerable throughout the region. Rock shrimp have historically been harvested in small quantities in northwest Florida and Mexico, although the reported 1979 catch reached 3,300 tons.

Spiny lobster

Total reported landings of spiny lobster in the Western Central Atlantic were 31,000 tons in 1978 and have increased by 11,000 tons since the 1960s. Lobster are harvested principally with wooden and wire pots on coralline shelf areas in Florida, throughout the Caribbean islands and in certain locations in Central America, Venezuela and northern Brazil. Major producing countries are Cuba, Nicaragua, the Bahamas, Brazil and the U.S. Wise (1976) estimated the total potential yield in the WECAFC region as 42,000 tons.

Surplus production models were fitted to historical catch and effort data from the Brazilian fishery (Programa de PDP do Brasil, 1977) and from the west coast of Florida (Gulf of Mexico and South Atlantic FMCs, 1979a). Total MSY in Brazil was 8,800 tons and was exceeded in 1974. More recent catches have been about 7,000 tons a year. Fishing effort, however, has exceeded f_{MSY} by a considerable margin since 1972 and catch-per-unit-effort has declined from more than 1 kg/trap-day in 1965-1966 to 0.3 kg/trap-day during 1973-1977. Furthermore, separate analyses for unit fisheries north and south of the equator (WECAFC, 1979a) indicated that the major lobster fishery was north of the equator (MSY = 7,300 tons) and that the resource there was more heavily exploited.

An exponential surplus production model was fitted to three data sets compiled for the lobster fishery in western Florida and MSY estimates were adjusted upwards to include recreational landings, unreported commercial catches and the east coast (Florida) fishery. The analyses depended critically on 1970-1975 data since effort has increased dramatically since 1970. Catch-per-unit-effort in this

fishery dropped to low levels (13-15 kg/trap) during 1971-1974 and even lower (5.5-6.5 kg/trap) in 1975 and 1976. Adjusted MSY estimates ranged from 2,500 to 3,350 tons. The "best" estimate of MSY for the west coast commercial fishery (2,500 tons) was exceeded in 1970 and 1974 and f_{MSY} was exceeded in 1974-1976.

Yield-per-recruit models were applied to parameter estimates from the Florida west coast (Gulf of Mexico and South Atlantic FMCs, 1979a) and Jamaica (Munro, 1974a). These analyses were hindered by questionable estimates of natural mortality. In Florida, Y/R curves predicted for three probable estimates of M and two probable estimates of K were "flat-topped", indicating that only very small increases in yield could be obtained from considerable increases in effort. Fishing mortality was estimated from the regression of total mortality versus effort. For average parameter values, the model predicted that the fishery was exploiting 95% of the maximum Y/R, but that the same yield could be taken with 50% less effort. This conclusions generally confirmed the results of the catch and effort data analysis.

In Jamaica, total and natural mortality rates were estimated from catch curves obtained from exploited and unexploited populations on Pedro Bank and the south coast of Jamaica. Natural mortality was reduced according to the abundance of predatory fishes and F was calculated from estimates of relative fishing effort and the catchability coefficient. Growth was inferred from tagging studies. The results indicated that size-at-first-capture would have to be doubled in order to achieve maximum Y/R for the heavily exploited south Jamaican fishery. The Pedro Bank stock, on the other hand, is under-exploited.

MSY estimates were also available for small lobster fisheries in the U.S. Virgin Islands and Puerto Rico (Caribbean FMC, 1978) and for Los Roques Archipelago in Venezuela, Cabo de Barany et al. (1972). In both cases, current catches were predicted to be at or near MSY.

Equilibrium yield models can provide reliable MSY estimates for long-lived lobster populations which are fairly independent of environmental variables. Problems which complicate management, however, are the possible transport of planktonic larvae by surface currents and the migration of adults over fairly long distances. Regional management strategies should be considered, especially in areas like the Lesser Antilles and Central America where fishing grounds of different countries are in close proximity.

Crabs

Reported commercial landings of crabs in the WECAFC area (about 40,000 tons a year during the past 20 years) are composed primarily of blue crabs (*Callinectes* spp.). Landings are reported from the U.S., Mexico and Brazil. Most of the estimated 12,000 tons harvested by U.S. recreational fishermen in 1975 were presumably blue crabs. A small, but important, stone crab (*Menippe mercenaria*) fishery is conducted in Florida. Stone crabs are also harvested in Cuba.

A potential yield of 80,000-180,000 tons of crabs has been estimated for statistical area 31 (Gulland, 1971; Bullis et al., 1971). No assessments have been possible for blue crab stocks given the lack of effort information. The only available assessment was for the Florida stone crab fishery (Gulf of Mexico FMC, 1979b). Linear and exponential surplus production models were fitted to 1962-1978 catch and effort data; catch was in claw weight (equal to one-half whole weight) and effort was measured as the number of traps. MSY estimates were increased by 20% to account for unreported recreational catch. Neither form of the model fits the data well and neither model predicted the observed catch after the 1972-1973 season. It is also possible that the number of traps actually in use was not reliably measured. The fishery expanded into deeper water in the early 1970s, causing a surge in catch and effort. CPUE has declined to less than 4 kg/trap since 1971-1972. Management of this fishery is complicated by the fact that only the claws are harvested; captured crabs are returned to the water to regenerate new claws.

Molluscs

A great variety of gastropods, bivalves and cephalopods are harvested in coastal waters of the Western Central Atlantic by industrial and artisanal fisheries. Reported landings (260,000 tons in 1978)

certainly under-estimate total catch since many species are harvested by hand and not reported. 36,000 tons of shellfish (excluding crabs) were reportedly harvested by U.S. recreational fishermen alone in 1975. The major commercial fisheries are for oysters (Crassostrea virginica) in the U.S. and Mexico, scallops (Argopecten gibbus and A. irradians) in the U.S. and ark clams (Arca zebra) in Venezuela. Other species which support valuable export trade in the Caribbean are conch (mostly Strombus gigas) and octopus. Aside from a few estimates of biomass on localized fishing grounds, assessments of these species in the WECAFC area are lacking. Most of the currently exploited species are underutilized.

Squid resources are almost totally unexploited at present. Gulland (1971) suggested a total cephalopod potential of more than 100,000 tons in area 31, possibly as much as 0.5-1.0 million tons. A number of species of coastal and oceanic squid are present in the region and could be harvested. Feeding or spawning concentrations of squid were not observed during exploratory fishing operations in the Gulf of Mexico (Rathjen et al., 1979). Such concentrations are required to support efficient harvesting.

REFERENCES

Allen, D.M. and J.E. Tashiro, 1976 Status of the U.S. commercial snapper-grouper fishery. In Proceedings of the colloquium on snapper-grouper fishery resources of the Western Central Atlantic Ocean, edited by H.R. Bullis and A.C. Jones. Fla.Sea Grant Rep., (17):41-76

Allen, K.R., 1953 A method for computing size-limit for a fishery. Nature,Lond., 172(4370):210

Anderson, W.W., 1970 Contributions to the life histories of several penaeid shrimps (Penaeidae) along the south Atlantic coast of the United States. Spec.Sci.Rep.USFWS (Fish.), (605):24 p.

Arostegui, A., Resultados de la compaña de pesca exploratorio de pargo en el litoral Atlantico de Nicaragua. Panama, Western Central Atlantic Fisheries Commission (WECAFC), mimeo

Barans, C.A. and V.G. Burrell, Jr., 1976 Preliminary findings of trawling on the continental shelf off the southeastern U.S. during four seasons (1973-1975). Tech.Rep.S.C.Mar.Resour.Cent., (13):16 p.

Baxter, K.N., T. Cody and G. Zamara, 1976 Shrimp tagging studies in Texas and Mexico waters. Paper presented at MEXUS/Gulf meeting, Miami, 22-23 November 1979 (Abstr.)

Beaumariage, D.S., 1973 Age, growth and reproduction of king mackerel, Scomberomorus cavalla, in Florida. Publ.Fla.Mar.Resour., (1):45 p.

Berry, R.J., 1967 Dynamics of the Tortugas (Florida) pink shrimp populations. Ph.D. Thesis. Ann Arbor, Michigan, University Microfilms, 177 p.

______ 1970 Shrimp mortality rates derived from fishery statistics. Proc.Gulf Carib.Fish.Inst., 22:66-78

Boardman, C. and D. Weiler, 1980 Aspects of the life history of three deepwater snappers around Puerto Rico. Proc.Gulf Carib.Fish.Inst., 32:158-72

Bullis, H.R., J.S. Carpenter and C.M. Roithmayr, 1971 Untapped west-central Atlantic fisheries. In Our changing fisheries, edited by S. Shapiro. Washington, D.C., U.S. Government Printing Office, pp. 74-391

Cabo de Barany, T., J. Ewald and E. Cadima, La pesca de la langosta en el archipiélago de los Roques,
1972 Venezuela. Inf.Tec.Proy.Invest.Desar.Pesq.MAC/PNUD/FAO, (43):14 p.

Caillouet, C.W. and D.B. Koi, Trends in ex-vessel value and size composition of landings of brown,
1980 pink and white shrimps from the Gulf and South Atlantic coasts of the United States. Mar.Fish.Rev., 42(12):18-27

Camber, C., A survey of the red snapper fishery of the Gulf of Mexico, with special reference to the
1955 Campeche Banks. Tech.Ser.Fla.State Board Conserv., (12):1-63

Caribbean Fishery Management Council, Draft fishery management plan for spiny lobsters, Puerto
1978 Rico and U.S. Virgin Islands. Prepared by NMFS, South Eastern Fisheries Center, Miami (mimeo)

Chapoton, R.B., The future of the Gulf menhaden, the United States' largest fishery. Proc.Gulf
1972 Carib.Fish.Inst., 24:134-43

Chittenden, M.E., Jr., Simulations of the effects of fishing on the Atlantic croaker, Micropogon
1977 undulatus. Proc.Gulf Carib.Fish.Inst., 29:68-86

Chittenden, M.E., Jr. and J.D. McEachran, Potential demersal-fish resources in the northwest Gulf of
1976 Mexico. In Proceedings of the First Annual Tropical and Subtropical Fisheries Technological Conference, compiled by B.F. Cobb III and A.B. Stockton. College Station, Texas, Texas A and M University, Sea Grant College, Vol.2:TAMU-SG-77-105:523-37

Clark, J.R., The 1960 salt water angling survey. Circ.USFWS, (153):36 p.
1963

Coelho, R.R., et al., Curvas de rendimento das lagostas, Panulirus argus (Latreille), and Panulirus
1974 laevicauda (Latreille), do Nordeste Brasileiro. Bol.Recurs.Nat.SUDEPE, 12(1):5-13

Colette, B.B. and J.L. Russo, An introduction to the Spanish mackerels, genus Scomberomorus. In
1979 Proceedings of the Mackerel Colloquium Gulf States Marine Fisheries Commission, Ocean Springs, Miss., 4:3-16

Corredor, J.E., Aspects of phytoplankton dynamics in the Caribbean Sea and adjacent regions. FAO
1977 Fish.Rep., (200):101-14

Costa, R.S., et al., Relatório da pesca da lagosta. Relatório da primeira reuniao da grupo de trabalho
1974 e treinamento solve avaljação dos estoques. Ser.Doc.Tec.Programa Pesqui.Desenvolv. Pesq.Bras., (7):79-87

Costello, T.J. and D.M. Allen, Mortality rates in populations of pink shrimp, Penaeus duorarum, on the
1968 Sanibel and Tortugas grounds, Florida. Fish.Bull.USFWS, 66(3):491-502

Cummins, R., Jr., Calico scallops of the southeastern United States, 1959-69. Spec.Sci.Rep.
1971 NOAA/NMFS, (627):22 p.

Davis, G.E., Effects of recreational harvest on a spiny lobster, Panulirus argus, population.
1977 Bull.Mar.Sci., 27(2):223-36

Dawson, C.E. and C.P. Idyll, Investigations on the Florida spiny lobster, Panulirus argus (Latreille).
1951 Tech.Ser.Fla.State Board Conserv., (2):1-39

Deuel, D.G., The 1970 salt water angling survey. Curr.Fish.Statist.NOAA/NMFS, (6200):54 p.
1973

Deuel, D.G. and J.R. Clark, The 1965 salt water angling survey. Resour.Publ.Bur.Sport Fish.
1968 Wildl.U.S., (67):51 p.

Doi, T. and D. Mendizabal, Evaluación preliminar de la población de sierra, Scomberomorus maculatus
1979 (Mitchill), frente a las costas de Veracruz. In Proceedings of the Mackerel Colloquium, Gulf States Marine Fisheries Commission, Ocean Springs, Miss., 4:43-56

Dryfoos, R.L., R.P. Cheek and R.L. Kroger, Preliminary analyses of Atlantic menhaden, Brevoortia
1973 tyrannus, migrations, population structure, survival and exploitation rates and availability as indicated by tag returns. Fish.Bull.NOAA/NMFS, 71:719-34

Eldridge, P.J. and S.A. Goldstein (eds), The shrimp fishery of the South Atlantic United States: a
1975 regional management plan. Tech.Rep.S.C.Mar.Resour.Cent., (8):64 p.

FAO, Yearbook of fishery statistics. Annuaire statistique des pêches. Annuario estadistico de pesca.
1979 Catches and landings. Captures et quantites debarquées. Capturas y desembarques. Yearb.Fish.Stat./Annu.Stat.Pêches/Anu.Estad.Pesca, (46):371 p.

Febres Ortega, G. and L.E. Herrera, Circulación y transporte de masa de aqua en el Caribe
1978 suroriental. FAO Fish.Rep., (200)Suppl:21-33

Fischer, W. (ed.), FAO species identification sheets for fishery purposes: Western Central Atlantic
1978 (Fishing Area 31). Rome, FAO, Vol.VI:pag.var.

Frederick, M.B. and D.M. Weidner, The Brazilian lobster industry, 1976. Foreign Fish.Leafl.
1978 NOAA/NMFS, (78-2):17 p.

Giudicelli, M., Exploratory and stimulated commercial fishing operations in the western Caribbean
1971 Sea, R/V "Canopus", May to November 1970. Bol.Tec.Proy.Reg.Desarr.Pesq.Centroam.El Salvador, 5(2):77 p.

Grant, W.E. and W.L. Griffin, A bioeconomic model of the Gulf of Mexico shrimp fishery.
1979 Trans.Am.Fish.Soc., 108(1):1-13

Griffin, W.L. and B.R. Beattie, Economic impact of Mexico's 200 mile offshore fishing zone on the
1978 U.S. Gulf of Mexico shrimp fishery. Land Econ., 54:27-38

Griffin, W.L., M.L. Cross and J.P. Nichols, Effort measurement in the heterogeneous Gulf of Mexico
1977 shrimp fishery. Dep.Tech.Rep.,Dep.Agric.Econ.Tex.Agric.Exp.Stn., (77.5)

Griffiths, R.C. and J.G. Simpson, An evaluation of the present levels of exploitation of the fishery
1972 resources of Venezuela. Ser.Recurs.Explot.Pesq.MAC/PNUD/FAO, 2(5):52 p.

Gulf of Mexico Fishery Management Council, Fishery management plan for groundfish (Gulf of
1978 Mexico), preliminary draft, Nov.1, 1978. Prepared by a Gulf Council task team directed by the Southeast Fisheries Center, National Marine Fisheries Service, Miami, Florida (mimeo)

__________, Draft fishery management plan for the shark and other elasmobranch fishery of the
1979 Gulf of Mexico. Prepared by the National Marine Fisheries Service, South Eastern Region, St. Petersburg, Florida (mimeo)

__________, Draft fishery management plan for reef fish resources of the Gulf of Mexico. Prepared
1979a by Florida Sea Grant College, Gainesville, Florida

__________, Fishery management plan for the stone crab fishery of the Gulf of Mexico.
1979b Fed.Register, 44(65):19445-96

__________, Fishery management plan for the shrimp fishery of the Gulf of Mexico, United States
1980 waters. Prepared by the Center for Wetlands Resources, Louisiana State University, Baton Rouge, La.

Gulf of Mexico and South Atlantic Fishery Management Councils, Draft fishery management plan for
1979 the coastal migratory pelagic resources (mackerels). Prepared by Centaur Associates, Washington, D.C. (mimeo)

__________, Draft fishery management plan for the spiny lobster resource. Prepared by Centaur
1979a Associates, Washington, D.C.

Gulland, J.A., The fish resources of the ocean. West Byfleet, Surrey, Fishing News (Books) Ltd., for
1971 FAO, 255 p. Rev.ed.of FAO Fish.Tech.Pap., (97):425 p. (1970)

Gutherz, E.J., The northern Gulf of Mexico groundfish fishery, including a brief life history of the
1977 croaker (*Micropogon undulatus*). Proc.Gulf Carib.Fish.Inst., 29:87-101

Gutherz, E.J. and P.A. Thompson, Jr., Sciaenid stocks of the western central Atlantic between
1977 Chesapeake Bay, Virginia and the Amazon River, Brazil. *In* Proceedings of the Second Annual Tropical and Subtropical Fisheries Technological Conference of the Americas, compiled by R. Nicholson II. College Station, Texas, Texas A and M University Sea Grant College, TAMU-SG-78-101:1-13

Holden, M.J., Problems in the rational exploitation of elasmobranch populations and some suggested
1974 solutions. *In* Sea fisheries research, edited by F.R. Harden Jones, London, Paul Elek, pp. 117-37

Houde, E.D., Abundance and potential yield of the round herring, *Etrumeus teres*, and aspects of its
1977 early life history in the eastern Gulf of Mexico. Fish.Bull.NOAA/NMFS, 75:61-89

__________ Abundance and potential yield of the thread herring, *Opisthonema oglinum*, and
1977a aspects of its early life history in the eastern Gulf of Mexico. Fish.Bull.NOAA/NMFS, 75:493-512

__________, Abundance and potential yield of the scaled sardine, *Harengula jaguana*, and aspects of
1977b its early life history in the eastern Gulf of Mexico. Fish.Bull.NOAA/NMFS, 75:613-28

Houde, E.D., *et al.*, Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Report to
1979 the Bureau of Land Management prepared under Contract No. 44550-CT7-28:73 p.

Huntsman, G.R. and C.S. Manooch, III, Coastal pelagic and reef fishes in the South Atlantic Bight.
1978 Mar.Recreat.Fish., 3:97-106

Huntsman, G.R., et al., Yield per recruit models of some reef fishes of the U.S. South Atlantic Bight. Beaufort, N.C., Beaufort Laboratory, South East Fisheries Center, NMFS (Unpubl.MS)

Jones, A.C. and A. Dragovich, The United States shrimp fishery off northeastern South America
1977 (1972-74). Fish.Bull.NOAA/NMFS, 75(4):703-16

Kawaguchi, K., Handline and longline fishing exploration for snapper and related species in the
1974 Caribbean and adjacent waters. Mar.Fish.Rev., 36(9):8-30

Keiser, R.K., Jr., The incidental catch from commercial shrimp trawlers of the South Atlantic states.
1977 Tech.Rep.S.C.Mar.Resour.Cent., (26):38 p.

Kleijn, L.J.K., Results of experimental and exploratory shark fishing off northeastern South America.
1974 Mar.Fish.Rev., 36(9):67-77

Klima, E.F., Aspects of the biology and the fishery for Spanish mackerel, Scomberomorus maculatus
1959 (Mitchell), of southern Florida. Tech.Ser.Fla.State Board Conserv., (27):39 p.

Mark-recapture experiments with brown and white shrimp in the northern Gulf of
1964 Mexico. Proc.Gulf Carib.Fish.Inst., 16:52-64

________, A white shrimp mark-recapture study. Trans.Am.Fish.Soc., 103:107-13
1974

________ A review of the fishery resources in the Western Central Atlantic. WECAF Stud.,
1976 (3):77 p.

________ An assessment of the fish stocks and fisheries of the Campeche Bank. WECAF Stud.
1976a (5):24 p.

Klima, E.F. and J.A. Benigno, Mark-recapture experiments. In Biological Laboratory, Galveston,
1965 Texas, fishery research for the year ending June 30, 1964. Circ.USFWS, (230):38-40

Klima, E.F. and M. Parrack, Constraints on food production from wild penaeid shrimp stocks in the
1978 Gulf of Mexico. In Drugs and food from the sea: myth or reality? edited by P.N. Kaul and C.J. Sundermann. Norman, Oklahoma, University of Oklahoma Press, pp. 317-30

Kutkuhn, J.H., Dynamics of a penaeid shrimp population and management implications. Fish.Bull.
1966 USFWS, 65:313-38

Leak, J.C., Distribution and abundance of Carangidae (Pisces, Perciformes) larvae in the eastern Gulf
1977 of Mexico, 1971-1974. University of Miami, Master's Thesis, 83 p.

Lindner, M.J., What we know about shrimp size and the Tortugas fishery. Proc.Gulf Carib.Fish.Inst.,
1966 18:18-26

________, Shrimp resources of the Caribbean and adjacent regions. FAO Fish.Rep., (71.2):149-56
1971

Margalef, R., 1971 The pelagic ecosystem of the Caribbean Sea. In Symposium on Investigations and Resources of the Caribbean Sea and Adjacent Regions, preparatory to the Cooperative Investigations of the Caribbean and Adjacent Regions (CICAR) organized through the joint efforts of FAO and UNESCO. Willemstad, Curacao, Netherlands, Antilles, 18-26 November, 1968. Papers on physical and chemical oceanography, marine geology and geophysics and marine biology. Paris, Unesco, pp. 483-98

McCoy, E.G., 1968 Migration, growth and mortality of North Carolina pink and brown penaeid shrimps. Spec.Sci.Rep.,N.C.Dep.Conserv.Dev., (15):26 p.

Melo, A.F.M., 1976 Aspectos biologico-pesqueros de *Epinephelus morio* (Val.), "mero". In Memorias del Primer Simposio Nacional de Recursos Pesqueros Marinas de Mexico. Mexico, Instituto Nacional de Pesca, Tomo 2:223-66

Menzies, R.A. and J.M. Kerrigan, 1979 Implication of spiny lobster recruitment paterns in the Caribbean - a biochemical genetic approach. Proc.Gulf Carib.Fish.Inst., 31:164-78

Metcalf, W.G., 1978 Water exchange between the Atlantic Ocean and the Caribbean Sea. FAO Fish.Rep., (200)Suppl:63-77

Molinari, R.L., *et al.*, 1980 Surface currents in the Caribbean Sea as deduced from satellite tracked drifters. Proc.Gulf Carib.Fish.Inst., 32:106-13

Munro, J.L., 1974 The biology, ecology, exploitation and management of Caribbean reef fishes. Scientific report of the ODA/UWI Fishery Ecology Research Project, 1969-1973. Part III. The composition and magnitude of line catches in Jamaican waters. Res.Rep.Zool.Dep. Univ.W.I., (3/III):27 p.

__________, 1974a The biology, ecology, exploitation and management of Caribbean reef fishes. Scientific report of the ODA/UWI Fishery Ecology Research Project 1969-1973. Part VI. The biology, ecology and bioeconomics of Caribbean reef fishes. Crustaceans (spiny lobsters and crabs). Res.Rep.Zool.Dep.Univ.W.I., (3(Vi):57 p.

__________, 1974b The biology, ecology, exploitation and management of Caribbean reef fishes. Scientific report of the ODA/UWI Fishery Ecology Research Project, 1969-1975. Part Vm. Summary of biological and ecological data pertaining to Caribbean reef fishes. Res.Rep.Zool.Dep.Univ.W.I., (3/Vm):24 p.

__________, 1979 Actual and potential fish production from the coralline shelves of the Caribbean Sea. FAO Fish.Rep., (200):301-22

Munro, J.L. and R. Thompson, 1973 The biology, ecology, exploitation and management of Caribbean reef fishes. Scientific report of the ODA/UWI Fisheries Ecology Research Project 1969-1973. Part II. The Jamaican fishing industry, the area investigated and the objectives and methodology of the ODA/UWI Fisheries Ecology Research Project. Res.Rep.Zool. Dep.Univ.W.I., (3/II):44 p.

Munro, J.L., P.H. Reeson and V.C. Gaut, 1971 Dynamic factors affecting the performance of the Antillean fish trap. Proc.Gulf Carib.Fish.Inst., 23:184-94

Naidu, K.S. and L.K. Boerema, 1972 The high-sea shrimp resources off the Guyanas and northern Brazil. FAO Fish.Circ., (141):18 p.

NMFS (National Marine Fisheries Service), Preliminary forecast of 1980 Atlantic and Gulf menhaden
1979 purse-seine catches. Beaufort, N.C. Southwest Fisheries Center (mimeo)

____________, Some aspects of biological and monetary harvest optimization in the Tortugas pink
1979a shrimp fishery. Galveston, Texas, Galveston Laboratory, Fisheries Data Analysis Division, Southeast Fisheries Center (mimeo)

Nelson, W.R., M.C. Ingham and W.E. Schaaf, Larval transport and year-class strength of Atlantic
1977 menhaden, Brevoortia tyrannus. Fish.Bull.NOAA/NMFS, 75(1):23-41

Nichols, J.P., W.L. Griffin and V. Blomo, Economic and production aspects of the Gulf of Mexico
1978 shrimp fishery. In Drugs and food from the sea: myth or reality? edited by P.N. Kaul and C.J. Sindermann. Norman, Oklahoma, University of Oklahoma, pp. 301-15

Nicholson, W.R., Movements and population structure of Atlantic menhaden indicated by tag returns.
1978 Estuaries, 1(3):141-50

Novoa, D. and E. Cadima, Evaluacion preliminar de la pesqueria de arrastre del camaron en la zona
1972 nor-oriental de Venezuela. Inf.Tec.Proy.Invest.Desarr.Pesq.MAC/PNUD/FAO, (42):24 p.

Olaechea, A. and C. Hernandez, Resultados obtenidos en las arrastres conjuntos de dos tipos de
1975 embarcaciones en el Banco de Campeche. Resum.Invest.Inst.Nac.Pesca Cent.Invest. Pesq.,Cuba, (2):153-7

Olsen, O.A. and I.G. Koblick, Population dynamics, ecology and behaviour of spiny lobsters, Panulirus
1975 argus, of St. Johns, U.S. V.I. 2: Growth and mortality. Bull.Nat.Hist.Mus.Los Angeles County, (20):17-21

Paiva, M.P., R.C.F. Bezerra and A.A. Fonteles Filho, Tentativa de avaliacao dos recursos pesqueiros
1971 do nordeste brasileiro. Arq.Cient.Mar,Fortaleza, 11(1):1-43

Parrack, M.L., Aspects of brown shrimp in the northern Gulf of Mexico. Galveston, NMFS, 26 p. (Prepubl.MS)

Peacock, N., A study of the spiny lobster fishery of Antigua and Barbuda. Proc.Gulf Carib.
1974 Fish.Inst., 26:117-30

Pella, J.J. and P.K. Tomlinson, A generalized stock production model. Bull.I-ATTC, 13:419-96
1969

UNDP/MAC, Politicas de desarrollo pesquero de Venezuela. Sinopsis de una unidad de pesqueria.
1979 United Nations Development Program (UNDP). Caracas, Ministerio de Agricultura y Cria (MAC), Tomo 3

Powell, D., Age, growth and reproduction in Florida stocks of Spanish mackerel, Scomberomorus
1975 maculatus. Fla.Mar.Res.Publ., (5):21 p.

Powles, H. and C.A. Barans, Evaluation of methods for monitoring groundfish of nearshore sponge-coral habitats off the southeastern United States (in preparation)

Pristas, P.J., E.J. Levi and R.L. Dryfoos, Analysis of returns of tagged Gulf menhaden.
1976 Fish.Bull.NOAA/NMFS, 74(1):112-7

Racca, E. and R.C. Griffiths, Primera evaluación de los recursos demersales del Golfo de Venezuela.
1972 Inf.Téc.Proy.Invest.Desarr.Pesq.MAC/PNUD/FAO, (53):24 p.

Rathjen, W.F., R.F. Hixon and R.T. Hanlon, Squid fishery resources and development in the northwest
1979 Atlantic and Gulf of Mexico. Proc.Gulf Carib.Fish.Inst., 31:145-57

Reintjes, J.W., A review of the clupeoid and carangid fishery resources in the western central
1979 Atlantic. Panama, Inter-Regional Project for the Development of Fisheries in the Western Central Atlantic (WECAF), 49 p. (mimeo)

Pelagic clupeoid and carangid resources for fishery development in the Gulf of Mexico
1979a and Caribbean Sea. Proc.Gulf Carib.Fish.Inst., 31:33-49

Robins, C.R., Distribution patterns of fishes from coastal and shelf waters of the tropical western
1971 Atlantic. FAO Fish.Rep., (77.2):249-56

Robinson, R.K. and D. Dimitriou, The status of the Florida spiny lobster fishery, 1962-1963.
1963 Tech.Ser.Fla.State Board Conserv., (42):27 p.

Rohr, B.A. and E.J. Gutherz, Biology of offshore hake, Merluccius albidus, in the Gulf of Mexico.
1977 Fish.Bull.NOAA/NMFS, 75(1):147-58

Salaya, J.J. and P.E. Penchaszadeh, Pesqueria de la vieira en Venezuela. Proc.Gulf Carib. Fish.Inst.,
1979 31:105-26

Salaya, J.J., R. Guzman and P.E. Penchaszadeh, Primera evaluación de la pesquería de arrastre en
1980 Golfo Triste y áreas adyacentes, zona centro-accidente, Venezuela. Proc.Gulf Carib. Fish.Inst., 32(Abstr.)

Santos, E.P. dos, P. de Alcantara Filho and C.A.S. Rocha, Curvas da rendimento de lagostas no estado
1973 de Ceará (Brasil). Arq.Cienc.Mar Fortaleza, 14(2):131-3

Santos, E.P. dos, R.S. Costa and S.J.C. Moura, Growth of the spiny lobster, Panulirus argus (Latr.):
1964 quantitative aspect. Arq.Estac.Biol.Mar.Univ.Ceará Fortaleza, 4(2):41-4

Sauskan, V.I. and D. Olaechea, Ictiofauna bentónica del Banco de Campeche. Resum.Invest.Inst.Nac.
1974 Pesca Cent.Invest.Pesq.,Cuba, (1):102-6

Savage, T., J.R. Sullivan and C.E. Kalman, An analysis of stone crab (Menippe mercenaria) landings on
1975 Florida's west coast, with a brief synopsis of the fishery. Fla.Dep.Nat.Resour.Mar.Res. Lab., (13):37 p.

Schaaf, W.E., Status of the Gulf and Atlantic menhaden fisheries and implications for resource
1975 management. Mar.Fish.Rev., 37(9):1-9

Schaaf, W.E. and G.R. Huntsman, Effects of fishing on the Atlantic menhaden stock, 1955-1969.
1972 Trans.Am.Fish.Soc., 101(2):290-7

Schaaf, W.E., J.E. Sykes and R.B. Chapoton, Forecasts of Atlantic and Gulf menhaden catches based
1975 on the historical relation of catch and fishing effort. Mar.Fish.Rev., 37(10):5-9

South Atlantic Fishery Management Council, Second draft of fishery management plan for the
1978 snapper-grouper complex of the South Atlantic region. Phase 1: Description of the fishery, December 1978

Stevely, J.M., The biology and fishery of the queen conch (Strombus gigas): a review. In Proceedings
1979 of the Fourth Annual Tropical and Subtropical Fisheries Technological Conference of the Americas. College Station, Texas, Texas A and M University, Sea Grant College, TAMU-SG-80-101:203-10

Stevenson, D.K. and N. Marshall, Generalizations on the fisheries potential of coral reefs and
1971 adjacent shallow-water environments. In Proceedings of the Second International Symposium on coral reefs, conducted by the Great Barrier Reef Committee on board the M.V. MARCO POLO, cruising in the waters of the Great Barrier Reef Province, Australia, 22 June to 2nd July, 1973. Brisbane, the Great Barrier Reef Committee, Vol.1:147-56

Struhsaker, P., Demersal fish resources: composition, distribution and commercial potential of the
1969 continental shelf stocks off the southern United States. Fish.Ind.Res., 4(7):261-300

SUDEPE, Programa de Pesquisa e Desenvolvimento Pesquiro do Brasil, Relatorio de reuniao técnica
1977 sobre e pesca de lagostas no nordeste do Brasil. Brasilia, SUDEPE (mimeo)

__________, Programa de Pesquisa e Desenvolvimento Pesquiro do Brasil, Relatório da reuniao
1978 técnica sobre a pesca do pargo no norte e nordeste do Brasil. 23-25 de Março de 1978. Brasilia, SUDEPE (mimeo)

__________, Programa de Pesquisa e Desenvolvimento Pesquiro do Brasil, Relatorio da reuniao do
1978a grupo permanente de estudos sobre lagostas. 13-15 Dec. 1978. Brasilia, SUDEPE (mimeo)

__________, Programa de pesquisa e desenvolvimento pesquiro do Brasil, Relatorio da reuniao do
1979 grupo permanente di estudos sobre piramutaba. 28-30 Março de 1979. Brasilia, SUDEPE (mimeo)

Sullivan, J.R., Studies of the stone crab, Menipe mercenaria (Say, 1819) in the southwest Florida fishery. Fla.Mar.Res.Publ. (in press)

Slyvester, J.R., A preliminary study of length composition, distribution and relative abundance of
1974 three species of deep-water snappers from the Virgin Islands. J.Fish Biol., 6:43-9

Tashiro, J.E. and S.E. Coleman, The Cuban grouper and snapper fishery in the Gulf of Mexico.
1977 Mar.Fish.Rev., 39(10):1-6

Thompson, R.W., Results of the UNDP/FAO Bahamas deep water fishery survey 1972-1975. Proc.Gulf
1978 Carib.Fish.Inst., 30:44-70

Vazquez de la Cuerda, A.M., Circulación del agua en el suroeste del Golfo de Mexico. FAO Fish.Rep.,
1978 (200):Suppl:155-71

Vidaeus, L., An inventory of the Jamaican fishing industry. Rome, FAO, UNDP/FAO Caribbean
1970 Fishery Development Project, Report SF/CAR/REG 180 M9:47 p.

Vieria-Ferreira, M., Pesda de tubaroes nos estados de Pernambuco e Paraiba. In Pesca e
n.d. aproveitamento económico dos tubaroes de nordeste brasilero. Sér.Estud.Pesca Dep. Recurs.Nat.Div.Recur.Pesqueiras, (4)

Voss, G.L., Cephalopod resources of the world. FAO Fish.Circ., (149):75 p.
1973

Warner, R.E., C.L. Combs and D.R. Gregory, Jr., Biological studies of the spiny lobster, *Panulirus argus*, in south Florida. Proc.Gulf Carib.Fish.Inst., 29:166-83
1977

Western Central Atlantic Fisheries Commission (WECAFC), Report of the joint meeting of the Western Central Atlantic Fishery Commission Working Party on assessment of fish resources and Working Party on stock assessment of shrimp and lobster resources. Cartagena, Colombia, 18-23 November, 1977. FAO Fish.Rep., (211):103 p.
1978

__________, Report of the meeting of the Working Group on shrimp fisheries of northeastern South America, Panama City, Panama, 23-27 April 1979 (mimeo)
1979

__________, Working Party on Assessment of Fish Resources and Working Party on Stock Assessment of Shrimp and Lobster Resources, Report of the joint meeting of the Western Central Atlantic Fishery Commission Working Party on the assessment of fish resources, and Working Party on assessment of shrimp and lobster resources. Mexico City, Mexico, 26-29 November, 1979. FAO Fish.Rep., (235):41 p.
1980

White, M.L. and M.E. Chittenden, Jr., Age determination, reproduction and population dynamics of the Atlantic croaker, *Micropodonias undulatus*. Fish.Bull.NOAA/NMFS, 75(1):109-23
1977

Williams, R.O. and D.E. Sutherland, King mackerel migrations. In Proceedings of the Mackerel Colloquium, Gulf States Marine Fisheries Commission, Ocean Springs, Miss., 4:57 (Abstr.)
1979

Wise, J.P., An assessment of the crustacean resources of the western central Atlantic and northern southwest Atlantic. WECAF Stud., (2):60 p.
1976

Wolf, R.W. and G.R. Chislett, Trap fishing explorations for snapper and related species in the Caribbean and adjacent waters. Mar.Fish.Rev., 36(9):49-61
1974

Yusaki, M., Os recursos de peixes de arrasto ao largo da costa do Brasil. Sér.Doc.Téc.Programa Pesqui.Desenvolv.Pesq.Bras., (8):22 p.
1974

Zein-Eldin, Z.P. and G.W. Griffith, An appraisal of the effects of salinity and temperature on growth and survival of post-larval penaeids. FAO Fish.Rep., (57)Vol.3:1015-26
1969

SELECTED LIST OF FAO PUBLICATIONS ON THE RESULTS OF FISHERY RESOURCES APPRAISALS

The publications listed here are believed to be of wide interest. Many other publications of more local interest have been published by FAO regional bodies and regional development projects.

The available priced publications and main documents can be obtained on request from: the Distribution and Sales Unit, FAO, Via delle Terme di Caracalla, Rome 00100. A list of FAO Fisheries Department publications covering the years 1948-1978 is published as FAO Fisheries Circular (100) Rev.3.

Gulland, J.A., 1971 The fish resources of the oceans. West Byfleet, Surrey, Fishing News (Books) Ltd., for FAO, 255 p. Rev.ed. of FAO Fish.Tech.Pap., (97):425 p. (1970)

Naidu, K.S. and L.K. Boerema, 1972 The high-sea shrimp resources off the Guyanas and northern Brazil. FAO Fish.Circ., (141):21 p.

Voss, G.L., 1973 Cephalopod resources of the world. FAO Fish.Circ., (149):79 p.

Bacon, P.R., 1975 Review on research, exploitation and management of the stocks of sea turtles. FAO Fish. Circ., (334):19 p.

Uchida, R.N., 1975 Studies on skipjack in the Pacific: recent development in fisheries for skipjack tuna, *Katsuwonus pelamis*, in the Central and Western Pacific and the Indian Ocean. FAO Fish. Tech.Pap., (144):1-57

FAO/UNEP, 1976 The biology and status of stocks of small tunas. Report of an Ad hoc Committee of Specialists. Honolulu, Hawaii, U.S.A., 15-18 December 1975. FAO Fish.Tech.Pap., (154): 21 p.

Loh-Lee Low, 1976 Commercial fisheries data systems and catch summaries of the Northeast Pacific, 1952-72. FAO Fish.Circ., (341):23 p.

Everson, I., 1977 The living resources of the Southern Ocean. Rome, FAO. GLO/SO/77/1:156 p. (E,S)

Newman, G., 1977 The living marine resources of the Southeast Atlantic. FAO Fish.Tech.Pap., (178): 59 p. Issued also in French and Spanish

Okutani, T., 1977 Stock assessment of cephalopod resources fished by Japan. FAO Fish.Tech.Pap., (173): 62 p. Issued also in Japanese

Thurow, F.R., 1978 The fish resources of the Baltic Sea. FAO Fish.Circ., (708):22 p.

Uchida, R.N., 1978 The fish resources of the Western Central Pacific Islands. FAO Fish.Circ., (712):53 p.

Gjosaeter, J. and K. Kawaguchi, 1980 A review of the world resources of mesopelagic fish. FAO Fish. Tech. Pap., (193):151 p.

Gulland, J.A., Some problems of the management of shared stocks. FAO Fish.Tech.Pap., (206):22 p.
1980

Belveze, H. and J. Bravo de Laguna, Les ressources halieutiques de l'Atlantique centre-est. Deuxième
1980 partie: les ressources de la côte ouest-africaine entre 24°N et le détroit de Gibraltar. FAO Doc.Tech.Pêches, (186.2):64 p.

Troadec, J.-P. and S. Garcia (eds), The fish resources of the Eastern Atlantic. Part 1. The resources
1980 of the Gulf of Guinea from Angola to Mauritania. FAO Fish.Tech.Pap., (186.1):166 p. Issued also in French

Garcia, S. and L. Le Reste, Life cycles, dynamics, exploitation and management of coastal penaeid
1981 shrimp. FAO Fish.Tech.Pap., (203):215 p. Issued also in French

FAO, Department of Fisheries, Atlas of the living resources of the seas. Atlas des ressources biologiques des mers. Atlas de los recursos vivos del mar. Rome, FAO, rev.ed. (Trilingual) (in press)

NO: 11307

132 + 16

148